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NOTICE OF CHANGE OF ADDRESS.

On and after June 1 all communications for the Editor of the "Geological Magazine" should be addressed to R. H. Rastall, Esq., M.A., F.G.S., Christ's College, Cambridge. Letters for Dr. Henry Woodward, F.R.S., to be sent to Tudor Cottage, Clay Hill, Bushey, Herts. Books and parcels to be directed to Messrs. Dulau & Co., 34–36 Margaret Street, Cavendish Square, W. 1.

EDITORIAL NOTES.

BY the death of Sir Frank Crisp, Bart., on April 29, in his 77th year, science in general has lost a very generous supporter and a valuable fellow-worker. Late senior partner in the well-known City firm of Ashurst, Morris, Crisp & Co., solicitors, Throgmorton Avenue, he devoted fifty years to law, but gave all his leisure and much of his income to scientific pursuits. He was a keen student and lover of microscopic research, and was an ardent supporter and honorary secretary of the Royal Microscopical Society, for which Society he obtained a Royal Charter. From 1879 to 1889 Crisp wrote the bulk of the invaluable bibliographical abstracts in the Journal R.M.S., and generously supported the publication by every means in his power. He formed, with much knowledge and at great expense, a most instructive and remarkable collection of instruments from the very earliest known microscopes to those of the most modern and costly construction provided with a great series of lenses of every kind. These he presented to the nation for the new Science Museum at South Kensington, the delay in the completion of which (caused by the War) has hitherto prevented their exhibition to the public. Sir Frank was also a Fellow of the Linnean Society, on the Council of which he served for nearly forty years, filling the various offices of Treasurer, Vice-President, and Solicitor. He procured the modification of the Society's charter to cover the admission of women as Fellows in 1904. He was pre-eminent as a botanist and collector of rare and remarkable living plants, to procure which he spared no expense. In Alpine plants alone he has brought together upwards of four thousand different species. His rock-garden at Friar Park, Henley, crowned with an

accurate model of the Matterhorn, needed for its construction no less than 20,000 tons of Carboniferous Limestone from Yorkshire, and with the other gardens, caves, lakes, and cascades renders this beautiful spot one of the finest gardens in England. At the time of his death he was preparing a great work on *Gardens, Ancient and Modern*, for which he had gathered an ample library of rare and curious books.

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Now that Belgian scientific publications are beginning to reappear, we are not surprised to see, accompanying those of the Académie Royale, a "Rapport succinct sur l'Etat du Palais des Académies après le Départ des Allemands". This has been compiled by M. Louis le Nain, Secrétaire de la Commission Administrative, whose duty it was to report on the work necessary for restoring the apartments to a condition fit for their original purposes. From this report it is clear that the work of restoration will take some considerable time, as the building and its contents had suffered during the German occupation. Certain rooms had been used as hospital wards, one even being set aside for tubercular cases, others as store-rooms, and so on, thus necessitating some structural alteration. Everywhere M. le Nain found the utmost confusion, disorder, and filth; and the photographs accompanying his report show this to be the case.

The Library too had suffered; some books had disappeared, others were misplaced, but when found were in a damaged condition. This was particularly the case with the Stassart Collection. Certain Belgian busts and paintings had been disfigured, the portrait of Leopold I being decorated with an iron cross; others had been damaged.

M. le Nain therefore considers that the building must be thoroughly cleansed and repaired before it can be again used, and that the number of objects stolen, lost, or misplaced must be discovered. Some time must elapse before this can be accomplished.

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An oil-painting of Gideon Algernon Mantell has recently been presented to the Geological Society of London, by subscription among a number of the Fellows. Unfortunately, the history of this painting is not known. The collection of oil-paintings in the possession of the Society is very small, consisting of only nine, including the portrait of Mantell, and that of Dr. Henry Woodward, referred to in these notes in the April number. The other oil-paintings, at present, hung in the Society's Meeting Room, consist of the portraits of William Smith, Buckland, Lyell, De la Beche, Phillips, Huxley, and Prestwich. There is also the painting of the group of geologists at the meeting of the British Association at Newcastle in 1838. On the walls of the Council Room are hung the portraits of the former Presidents of the Society. This series is complete, and consists chiefly of engravings, with large photographs of the later Presidents.

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The veteran Swiss geologist, Albert Heim, attained his 70th birthday on April 12, 1919. The event has been duly commemorated by the publication of a Festschrift, issued by a special committee, with Dr. Paul Arbenz as chairman, as a double number of the Vierteljahrschrift der Naturforschenden Gesellschaft in Zurich. This is a handsomely prepared volume of 518 pages and 12 plates, and contains 24 separate contributions, besides a complete catalogue of Professor Heim's publications. Most of the contributions to this Festschrift naturally deal with various branches of the geology of Switzerland; other subjects, however, have received attention. Thus, A. Hartmann deals with the hydrology of the Magdalena Bay district, in Lower California; L. Zehnder contributes a short discussion on the causes of geological epochs; E. Blumer reviews the principal petroleum deposits; E. Bloesch gives an account of the tectonics of the Front Range in Colorado; while W. Staub presents the results of recent geological exploration in Eastern Mexico. The value of Albert Heim's own work is well recognized in this country; he was elected a Foreign Correspondent of the Geological Society of London in 1887, and was made a Foreign Member in 1896. It will be remembered that he was one of the six distinguished geologists on whom the University of Oxford conferred the honorary degree of D.Sc. on the occasion of the Society's Centenary in 1907.

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The views set forth in the Report of Sir Joseph Thomson's Committee on Scientific Education (*Report of the Committee of the Privy Council for Scientific and Industrial Research for the Year* 1917–18) are evidently endorsed by opinion in the Colonies. In the recently established New Zealand Journal of Science and Technology (the organ of the New Zealand Board of Science and Art), the matter is discussed by the editor under the title of "Training Research Workers". Certain passages are quoted from the Privy Council Report, and particular stress is laid on the prefatory exhortation to prompt action. In the opinion of the editors of this New Zealand Journal, even if scientific research were adequately endowed in the Dominion a dearth of investigators would be at once apparent. Granted that the true research spirit is a matter of natural ability rather than the result of training, it still remains that the potential worker must be able to get proper facilities for development. The War has made us aware of many deficiencies: one of these is the need of adequate scientific training of a University type. The feeling of the natural independence of the New Zealand youth is not confined to that Dominion; he wants to find himself as independent financially while pursuing his University course as he would if starting a business career. An extension of the scholarship system is the only means of attaining this except in the case of the rich.

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Geology and geography have so much in common that it is not always easy to draw the line between them. It is accordingly

a matter of some interest to the geologist that the University of Cambridge has recently established a Tripos in Geography. Hitherto geography has not been recognized by any British University as a subject for a degree in honours, and the highest distinction awarded was a Diploma, such as that of Cambridge or Oxford. The Diploma in Geography has proved a very valuable and useful qualification to teachers, but it did not carry with it an honours degree.

The new Tripos is divided into two parts. Part I corresponds very closely with the old examination for the Diploma, and will probably still remain the most useful qualification for teaching purposes. It covers a wide ground, and no candidate can pass it creditably without showing a sound and broad knowledge of all the different branches of geography. Part II is designed more for the specialist, and the man who intends to undertake original research takes up one or two sections only, but is required to study these more deeply and to be acquainted with the other branches of knowledge which bear upon the section which he selects. There is, for instance, a section "Geomorphology", and the student who chooses this must be a geologist. There is, however, a geographical side to geology, and it is to this, and its influence on surface features, rather than to details of stratigraphy, palæontology, and petrology, that he will devote most attention.

The other subjects in Part II are Geodetic and Trigonometrical Surveying, Oceanography and Climatology, Historical and Political Geography, and Economic and Commercial Geography.

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We referred recently in our Editorial Notes to the question of the existence of workable quantities of petroleum in England; since that date another important contribution to the subject has come to hand in the shape of a paper read to the Manchester Geological and Mining Society by Mr. T. Sington on "The Search for Petroleum in Derbyshire now in Progress". This paper describes the exact situation of the seven boreholes now being put down to the south-east of Chesterfield and their relations to the geological structure of the district. The author points out in the clearest terms that if any considerable amounts of oil or gas now exist in the rocks to be penetrated by these bores they have had every opportunity to show themselves, owing to the abundance of colliery workings in the neighbourhood, and he feels confident that none will be found. In the discussion that followed this view received the support of every speaker, including the weighty authority of Professor Boyd Dawkins, who pointed out that while petroleum is often found in the Coal-measures, it is always in quantities to be measured by a tea-spoon rather than a bucket, and that it is extremely improbable that at lower levels it will occur in any larger proportion. This entirely agrees with the views of the authorities already quoted. In this connexion the Editors are pleased to be able to say that they have in hand a valuable paper by Mr. V. C. Illing, which will be published in an early issue of the Magazine, after the conclusion of the paper on Potash by Dr. Holmes begun in the present number.

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Arising out of the previous question, as they say in Parliament, it is perhaps permissible once more to draw attention to a most important subject, namely, the proper examination, treatment, and preservation of the cores from borings. According to the details given by Mr. Sington, there will be no cores from the Derbyshire borings; nevertheless the principle is the same: all material obtained from deep bores should be inspected by competent geologists and the results carefully recorded. Cores are frequently treated in the most haphazard fashion, being examined only by the borer, who often records their character in jargon intelligible only in the district where they happen to be, and totally useless anywhere else. It is rarely that a core is inspected by a competent geologist and the results published in a scientific form. It is, of course, obvious that it may be necessary in certain cases that the details of a boring should be kept secret for a time, but in the national interest control should be compulsorily exercised over all borings, which should be inspected during their progress by Government geologists and the facts carefully registered as the work progresses. Thus intending prospectors could at any rate obtain information as to whether the work proposed had already been done in that particular district, and unnecessary expenditure thus prevented. One of the most important functions of applied geology is to prevent people wasting their money on fruitless enterprises.

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The Department of Mines of the Dominion of Canada has shown commendable promptitude in the issue of its "Preliminary Report of the Mineral Production of Canada during the Calendar Year 1918", which bears date February 27, 1919. One can only say *O si sic omnes!* The total value of the minerals produced during the year shows an increase of 10·8 per cent over that of 1917, while since 1913, the last complete year before the War, the increase is no less than 44·3 per cent. More than half of the increment of value since 1917 is due to the higher price of coal, while silver, cobalt, and asbestos reached considerably higher prices, the actual production of the two latter being also higher. Copper, lead, and molybdenite show a considerably greater output, but the price of the last has fallen off sadly, owing to the lessened demand for munition purposes. For the first time for some years a small output of tungsten is recorded from the Yukon, Manitoba, Nova Scotia, and New Brunswick. The nickel industry of the Sudbury district fully maintained its position, and many of the minor products and non-metallic minerals showed substantial increases, especially petroleum, magnesite, and gypsum. Altogether the mineral industry of the Dominion appears to have been in a flourishing condition in 1918.

ORIGINAL ARTICLES.

I.—Foliation and Metamorphism in Rocks.

By Professor T. G. Bonney, Sc.D., LL.D., F.R.S.

(*Concluded from p. 203.*)

In pressure-modified gneisses and schists certain minerals are often distinctly secondary in formation; actinolitic hornblende replaces ordinary hornblende in a gneiss, as on the southern side of the St. Gotthard Pass (**31**), or in a dark mica-schist, as in the Binnenthal (**32**), or a tremolite appears in marble near the Campolungo Pass (**33**). A mixture of crushed hornblende and felspar gives rise to a biotite, small flakes of which may be built, like bricks, into a newly-formed large crystal of hornblende, especially towards its exterior (**34**). Glaucophane in hornblendic rocks, such as diorites and eclogites, is often a secondary mineral (**35**), some constituents derived from a crushed soda-felspar having combined with those of the original hornblende. Rather large biotites have formed in a dark mica-schist in the Binnenthal, and here also some of them have been developed at right angles to the main pressure, but others in the direction of it (**36**). Scales of chloritoid, sometimes a third of an inch in diameter, are secondary formations in some gneisses and chloritic schists, and kyanites in some micaceous schists suggest a possible reconstruction of an original mineral. Chlorite itself is a mineral of secondary origin, and such rocks as smaragdite-euphotide (**37**), saussuritic gabbro, and possibly even ordinary gabbro[1] are all more or less altered from their original condition, and in some at least of these cases pressure may have been a factor in the change. Besides this, new felspars may be formed in rather basic igneous rocks which have been much crushed, such as the *grüner Schiefer* of the Alpine and other regions.[2] In most of these cases pressure has been essential as a preliminary factor (i.e. the rock must have been more or less crushed), but how far it has operated in the "rebuilding" process is less easily determined. Water has probably aided, and there may have been some, though not a great, elevation of temperature.

We can also find instances of intermediate or partial metamorphism, i.e. rocks in which an original fragmental structure has not been wholly obliterated. Of this the noted section at Obermittweida affords a striking example (**39**). Here a mass of gneiss, very probably of igneous origin but subsequently affected by pressure, is overlain by conglomerates and other sedimentary rocks. The matrix of the one and the materials of the other are sufficiently metamorphosed to

[1] Diallage may be always a mineral of secondary origin; at any rate, we can detect under the microscope grains of augite partly converted into it, and discover that the hornblende in not a few diorites was once an augite; but on the history of hornblendic gabbros it is needless to dwell (**38**).

[2] These, as it has been proved, are plagioclase, but with a higher percentage of silica and soda than the original mineral: albite or oligoclase, with a slightly porphyritic habit, forming in a rock of which labradorite was a constituent. These, it may be added, often fail to exhibit the characteristic oscillatory twinning.

convert what was once ordinary detritus into fine-grained mica (mostly biotite) and quartz, probably authigenous, but as that matrix becomes coarser, so the traces of a clastic origin grow more distinct, till that becomes conspicuous in the breccias or conglomerates. I recognize in their fragments under the microscope the following—granitoid rock (3 varieties), mica-schist (1), quartz-schist (4), quartzite (2), ? hälleflinta (2); still, even in these, mineral changes appear to have occurred, some of which at least may be later in date than the formation of the fragment.

The cuttings on the Canadian Pacific Railway on both sides of Sudbury Station exhibit similar cases of incomplete metamorphism.[1] Here we find two groups of rocks, one of which is more highly metamorphosed than the other, and is in much the same condition as that at Obermittweida. The matrix is an aggregate of biotite and quartz with some felspar. The first is mainly, the second to some extent, at least, authigenous, the third probably clastic, though it may have undergone subsequent augmentation. The larger fragments also exhibit some changes, secondary quartz and white mica being produced locally in the felspar, and the larger grains of quartz are replaced by a mosaic of this mineral. Biotite occurs more sparingly, in little flakelets, both clustered and isolated, which also suggests a breaking up of original constituents of that mineral. Another group, probably rather higher in position, occurs to the west of Sudbury, which contains fragments of volcanic rocks and shows less signs of metamorphism. There is also a group, traversed, as I was informed, by the railway from Sudbury Station to Algoma Mills and Saulte St. Marie, which seems to have been as much metamorphosed as the Upper schists of the Alps.[2] The important fact, however, in the two groups mentioned above is that, while retaining indubitable traces of clastic origin, they indicate very considerable mineral changes, which, however, differ from those directly resulting from either water, or pressure, or heat, when operating separately, though probably demanding a rather considerable and prolonged action of the last agent.

We pass now to rocks, the origin of which is indubitable and the metamorphism only micro-mineralogical. One instance will suffice, because this exhibits the most marked departure from its original condition, the group of the phyllites, a name often employed (as is almost inevitable) rather vaguely, but which may be conveniently restricted to argillaceous cleaved rocks, in which a minute secondary mica has been developed in such large quantities as to constitute the greatest part. These flakelets mostly lie in the same direction, i.e. perpendicular to the direction of maximum pressure; in fact, a phyllite is the first marked step in the passage from a slate to a schist. Phyllites occur in greatly folded districts, such as parts of the Alps, Brittany, Scandinavia, Scotland, and Wales; indeed, are frequent in mountain regions, past or present.

[1] Locally these are broken into by moderately coarse syenites, sometimes almost hornblende granites, and by basic rocks.

[2] A few specimens were shown to me at Sudbury.

One or two silicates, larger in size than the other constituents, are sometimes formed in this stage of metamorphism, but as they may become very impure by including material from the ground-mass, precise identification is often difficult, but they probably represent dipyr, couseranite, and a colourless chloritoid. In rare instances small idiomorphic garnets are found in rocks, the matrix of which shows little signs of change. These have a peculiar structure which distinguishes them from the ordinary garnet of true schists and igneous rocks, and are sometimes associated with "bunches" of small actinolitic hornblende, almost colourless. The evidence as to the origin of these minerals is not decisive, though it suggests the action of heated vapours (**42**).

The *knoten* and *prismen*, associated with crinoid and other organic relics of Liassic age, in the mountains above the Lukmanier Pass, on the eastern slope of the Nufenen Pass, and on or near the Nufenen Stock, are remarkable instances (**41**).

I have passed over one mineral, tourmaline, which is generally, if not always, a result of metamorphic action, because its mode of occurrence links it more closely with contact metamorphism. It is apparently the result of pneumatolytic action on the aluminous minerals in a rock, the felspars and the biotites in those of igneous origin (usually the granites) and the clayey constituents of the sedimentary. It also occurs in veins traversing these rocks, and especially granite masses, in association with quartz, fluor-spar, lithia-micas, chlorites, cassiterite, and one or two other minerals of less frequency, and the main difference from the ordinary results of contact metamorphism, which I have not discussed because they form so distinct a category, is that, as the tourmaline appears in the intrusive rock, which has produced that metamorphism, this mineral must be later in date than it.[1] Of this mode of occurrence the rock called luxulyanite is the most striking example (**43**).

The conversion of the felspar in a mass of granite into the material called china clay, so strikingly illustrated in the Devon–Cornwall region, and often closely associated with the tourmalinizing agencies, is strictly speaking a metamorphic process, and a still more striking change is occasionally found in the replacement of the quartz in a granite by fluor-spar (**44**).

Other igneous rocks have undergone conspicuous metamorphism since they first solidified. Of these the replacement of augite by hornblende, and felspar by saussuritic minerals, has already been mentioned, but some diabases exhibit still greater changes. These, however, so far as I have seen, occur only in small masses, and generally in regions where pressure appears to have co-operated with water. The result has been the removal of much SiO_2 and MgO, and the formation of a peculiar chlorite with a much higher percentage of alumina than in those ordinarily described (**45**).

But serpentine is the most conspicuous instance of an igneous

[1] It may also appear in the associated sedimentary rock, which shows the ordinary effects of contact metamorphism, but suggests by its mode of occurrence that it is due to some subsequent action.

rock subsequently metamorphosed. Originally a peridotite,[1] and frequently occurring in large masses, as at the Lizard and in the Alps, it has been converted by gradual change into a mass of flaky serpentine, as was described in my first paper on the Lizard, to which I have already referred,[2] and this rock also, by further action of water, may be altered with a talc-schist (46). An exceptional kind of chlorite-schist which occurs, apparently intrusive, in talcose-serpentine on the Gorner Grat and in Anglesey, has once been, as already mentioned, a diabase, and dykes of the latter can be seen at the Lizard occasionally to pass into varieties of "potstone", while the so-called white-trap is another modification of a basaltic rock too well known to need more than mention.

The metamorphic rocks still present difficulties—points in their history which require further elucidation—but during the last half-century, as I know from my own experience, and as any one can ascertain by consulting the books and papers, which at the beginning of that period were regarded as authorities, the mists which then obscured knowledge have been largely dispersed, and many misleading and erroneous notions have been banished.

The passage of sedimentary into igneous rocks, once so confidently asserted, has proved to be no better than a figment of the imagination. It is possible, of course, that a sedimentary rock may be melted down, especially if small fragments of it are caught up in large masses of molten material, but even these appear, as a rule, to be so refractory that little evidence can be found in its favour.[3] The gneiss and schists, the rocks commonly called metamorphic, prove, as a rule, to be more ancient than any strata to which a date can be assigned, and belong, apparently, to an era in the earth's history anterior to the appearance of life, when the temperature of its crust rose more rapidly in a downward direction than at the present day. This statement, fifty years ago, would have been scouted as heretical by most geologists; I think, however, that the bulk of those who have studied petrology, not only in the field, but also with the microscope, would now consider it to be the more probable hypothesis.

BIBLIOGRAPHICAL REFERENCES.

I have omitted my own name where, as in the majority of cases, the papers are written by myself. Q.J. denotes Quarterly Journal of the Geological Society, G.M. Geological Magazine, M.M. Mineralogical Magazine.

1. Q.J. xlvii, p. 476; lii, pp. 22, 27–30; "Crystalline Schists of the Lizard," pp. 21–33.
2. Q.J. xxxiii, p. 888; xxxix, pp. 11, 16.

[1] I believe it is generally a deep-seated rock which occurs more often in bosses than in dykes, and never, so far as I have been able to ascertain, as a flow.

[2] Perhaps the minutely flaky form of serpentine named antigorite may be due to subsequent pressure during or subsequent to the action of water (47).

[3] The dark patches in igneous rocks have been discussed in an excellent paper by Mr. J. A. Phillips (Q.J. xxxvi, pp. 1–22), but I regard them, more often than he has done, as remnants of fragments of much older rocks, or pieces of a more basic igneous rock that have been broken off and carried along by the moving magma.

3. (With E. Hill) Q.J. xlviii, p. 122.
4. Q.J. xlvii, pp. 475, 480 (with General Macmahon); xlviii, p. 135 (with E. Hill); lxviii, p. 32.
5. G.M. 1894, pp. 118, 119.
6. (With E. Hill) Q.J. lxviii, pp, 41–3.
7. Q.J. xlii, Proc., p. 68.
8. G.M. 1894, pp. 115, 116.
9. Proc. Geol. Assoc. xv, p. 6.
10. Q.J. xlii, Proc. pp. 70, 71.
11. G.M. 1894, p. 116.
12. C. Lapworth, "Secret of the Highlands": G.M. 1883, pp. 120, 193, 337.
13. *Geological Structure of North-West Highlands* (Mem. Geol. Surv.), pp. 472–3.
14. J. Lehmann, *Entstehung der Altkrystallinischen Schiefergesteine*, etc., 1884; more especially chapters xvi–viii.
15. Q.J. xlix, pp. 94–103, 105–112; l, pp. 279–284.
16. Q.J. xlv, pp. 93–7; liv, pp. 358–67.
17. J. B. Jukes, *Students' Manual of Geology*, 1872, (ed. A. Geikie), p. 144.
18. J. B. Jukes, *ut supra*, pp. 246, 366. Also A. H. Green, *Geology*, 1876, pp. 271, 292–5. By 1878 I had convinced myself from personal examination that the important cases mentioned at the latter reference were quite wrong.
19. *Crystalline Rocks of the Lizard*, 1914, pp. 9, 21–33.
20. Q.J. xlvi, pp. 199–204, 208–13, 217–21; l, 297–90.
21. Q.J. xlv, pp. 91, 92.
22. G.M. 1893, p. 204.
23. G.M. 1895, p. 400.
24. Q.J. xlvi, pp. 200–2.
25. Q.J. xlvi, p. 217.
26. Q.J. xlix, p. 89.
27. G.M. 1901, p. 166.
28. Q.J. 1894, pp. 297–300.
29. Q.J. 1899, pp. 91. 92.
30. Q.J. xl, pp. 3–5.
31. Q.J. liv, pp. 361–3.
32. Q.J. xlix, pp. 108–9.
33. Q.J. i, p. 299.
34. Q.J. liv, pp. 366–7.
35. M.M. vii, pp. 1, 151, 191; Q.J. xliii, p. 303.
36. Q.J. xlix, p. 106.
37. Phil. Mag. 1892, pp. 237–48.
38. Q.J. lxviii, p. 51.
39. Q.J. xliv, p. 25. See also T. M'K. Hughes, id., p. 20.
40. Q.J. xliv, pp. 33–9.
41. Q.J. xlii, Proc., 73–5; xlvi, 214–21, 299–301.
42. G.M. 1901, pp. 163–6. C. A. Raisin, Q.J. lvii, pp. 63–71.
43. M.M. i, pp. 215–21.
44. Trans. Geol. Soc. Cornwall, x, pp. 180–6. See also M.M. vi, p. 48.
45. G.M. 1890, pp. 538–41.
46. G.M. 1890, pp. 532–42; 1897,pp. 110–13.
47. (With C. A. Raisin) Q.J. lxi, pp. 699–714.

II.—Non-German Sources of Potash.

By Arthur Holmes, D.Sc., A.R.C.S., F.G.S.

Introduction—Natural History of Potash—Saline Deposits—Alsatian Deposits—Spanish Deposits—Abyssinian Deposits—Natural Brines—Searles Lake—Nebraska and Utah—Tunis—Saltpetre—Kelp—Other Organic Sources—Insoluble Potash Minerals—Felspars—Leucite—Glauconite—Alunite—Dust from Cement Kilns—Blast Furnace Flue-dust.

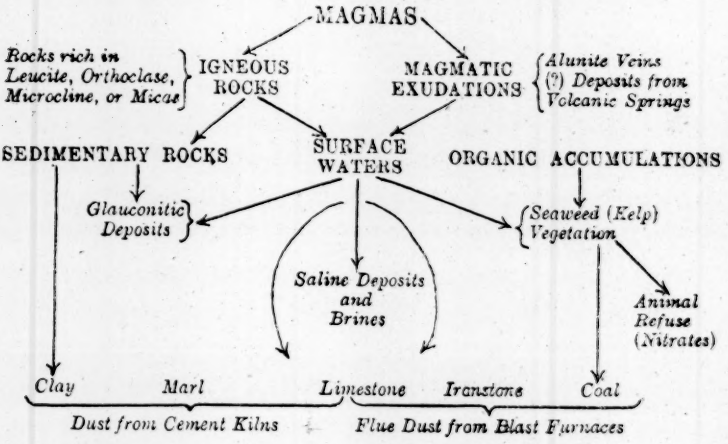
IT is scarcely necessary in this Magazine to insist upon the vital importance of potash, or upon the reasons which led to the former economic dependence of our own and many other countries on German resources. The shortage of potash, which arose as a direct consequence of the outbreak of war, became more and more accentuated until the latter part of 1917, when production from various revived and newly discovered sources began appreciably to relieve the then seriously acute position. In 1913, the last complete year of the older conditions, over £900,000 worth of potassium salts were imported from Germany by Great Britain, against imports of only half that value—much of which was cream-of-tartar, a by-product of the wine industry—from all other countries. It is now safe to say that the German monopoly is completely broken, partly because of the return of Alsace to France, and partly because of the discovery of new deposits, and the successful development, under the stimulus of war conditions, of new methods of potash recovery from sources formerly unremunerative or unsuspected. The purpose of this article is to pass briefly in review the chief sources from which potash is, or may be, profitably extracted, other than those of the famous German deposits, which already have a voluminous and familiar, or at least readily accessible, literature.

The natural history of potash is very different from that of soda. In average igneous rock the percentages of these two constituents are practically equal, while in average sedimentary (exogenetic) rocks potash is two and a half times as abundant as soda. Complementary to this selective retention, the potash of river waters amounts to no more than a quarter of the soda, and in sea water the proportion is still further reduced to a thirtieth. The following figures, based on denudational statistics, bring out clearly the difference of behaviour between the two elements.

	Potassium.	Sodium.
	(Figures represent millions of millions of tons.)	
In ocean water	450	12,600
In sedimentary rocks	18,300	7,400
	18,750	20,000
In parent igneous rocks from which the sediments were derived	19,700	20,000
Unaccounted for	950	—

In round figures the circulation of sodium is completely accounted for, whereas a large balance of potassium, twice the quantity dissolved in the oceans, remains over. This amount, or something

of the same order, must be mainly present in organisms. It is well known that potassium salts are preferentially adsorbed by colloidal and physically analogous substances from solutions that percolate through soils, and from the latter they are taken by plants, and thence by animals. Of the potash that reaches the sea a high proportion is similarly abstracted by seaweeds, while another considerable fraction is adsorbed by ferruginous and siliceous matter to form glauconite. Without going into further detail, the circulation of potash from its original magmatic sources is summarily set forth in the following scheme, with a view to indicating the deposits from which extraction is economically practicable, or likely to be come so if need arose:—



Saline Deposits.

In addition to the extensive German salt-fields,[1] generally referred to as the Stassfurt deposits, there are at least half a dozen areas where beds of potassium salts are associated in workable quantities with saline formations. Three of these, in Alsace, Spain, and Abyssinia, are of outstanding importance. In Galicia, Lower Miocene beds of kainite and sylvite are mined at Kalusz, but as the output is insufficient to supply the local demand, these deposits are, for us, of minor interest.[2] Numerous potash-bearing seams have been discovered in the mines of the Salt Range of India.[3] Their commercial development, however, has been restricted by the irregularity of the potash and the abundance of sulphates, and at present their exploitation has scarcely passed the prospecting stage. In Chile there are extensive salt deposits lying to the east of the nitrate fields, and one of these, the Pintados Salar, which is skirted

[1] J. W. Gregory, Trans. Geol. Soc. Glasgow, vol. xvi, p. 12, 1916.
[2] Zeit. für das Landwirtschaftliche Versuchswesen, vol. xviii, p. 892, 1914.
[3] W. A. K. Christie, Rec. Geol. Surv. India, vol. xliv, p. 243, 1914.

by the railway from Iquique, has been found by chemical prospecting to be potash-bearing over an area of 20 square miles.[1] The potash is confined to a hard superficial crust averaging a foot in thickness, which overlies a loose granular deposit of glauberite and gypsum. The composition of the crustal salts is approximately 70 per cent NaCl with 30 per cent of sulphates, among which glaserite, $(K, Na)_2 SO_4$, is the chief. As in the Indian deposits, the effective extraction of potash presents a difficult problem to chemical engineering. Deposits that hitherto have not been worked, and of which very little is known, are said to occur in Holland, Sicily, Russia, Morocco, and Peru.

Alsatian Deposits.—The Alsatian deposits were discovered near Mulhouse in 1904 during a survey of the district for coal and oil by borings. They have since been thoroughly investigated, and are known to underlie an irregular oval-shaped area of about 80 square miles,[2] bounded by the Jura on the south, the Vosges on the west, and the Rhine on the east. A continuation of the same formations has also been recognized across the Rhine, but as yet the occurrence of potash in Baden remains hypothetical. The general succession of the Alsace deposits is stated in the accompanying table in comparison with those of other areas. Potassium salts occur in two well-marked beds separated by 50 to 80 feet of dolomitic marl. The lower bed is both thicker and more extensive than the upper, and is encountered at depths varying from 2,000 to 3,300 feet in different parts of the field. The beds are continuous, and as they are only very gently folded, unlike the Spanish deposits described below, they can be worked without difficulty. Moreover, they are superior in character to the German deposits because of the absence of carnallite. Each bed consists of practically pure sylvinite, in bands alternately red and grey, the average percentages of KCl being 35 and 30 for the upper and lower beds respectively. The field, as a whole, is estimated to contain over 400 million tons of KCl, a reserve ample, were it necessary, to supply the combined requirements of France, Great Britain, and the United States for several centuries.

The Alsace deposits differ most conspicuously from those of other regions by the deficiency of sulphates, salts containing $MgSO_4$ being absent, while even anhydrite and gypsum are less abundant than is usual. On the other hand, the succession of deposits begins with dolomite, and dolomitic beds occur at various horizons throughout, indicating that calcium and magnesium were present in normal quantities, and that they were precipitated as carbonates rather than as sulphates. The absence of sulphate is not improbably due to the bituminous character of the deposits, and conforming to the implied suggestion of reduction the bituminous beds are found to be unusually rich in sulphides.

[1] H. S. Gale, Eng. & Min. Journ., vol. cv, p. 674, 1918; R. C. Wells, ibid., p. 678.

[2] For a map of the area and a general discussion of its commercial value and political significance, see Paul Kestner, Journ. Soc. Chem. Ind., vol. xxxvii, p. T 291, 1918.

Wittelsbach District, Alsace.	*Suria and Cardona District, Spain.*	*Southern Härz District, Germany.*
Oligocene marls . .	*Oligocene* marls, sandstones, and limestones. Marls with rock-salt, anhydrite, and gypsum.	*Triassic* / *Upper Permian* Sands, sandstones, clays, and shales.
Rock-salt and clay . .	Upper rock-salt . .	Younger rock-salt.
	Anhydrite	Anhydrite.
Dolomitic salt-marl .	Salt-clay	Salt-clay.
Zones of potash salts in dolomitic marl . .	Zones of potash salts .	Zones of potash salts.
Rock-salt with bituminous clays . . .	Lower rock-salt with partings of anhydrite.	Older rock-salt with partings of anhydrite (year rings).
Anhydrite	Anhydrite and gypsum.	Anhydrite and gypsum.
Dolomite.		
Green-grey marls . .	*Eocene* limestone . .	*Lower Permian* limestone.

Spanish Deposits.—Just before the war a zone of potash salts was discovered in Catalonia, near Cardona, a locality already well known for its rock-salt mines. The general succession has been revealed by a large number of bore holes and by a series of shafts which mark the beginning of the productive exploitation of the deposits. As shown in the detailed sequence set forth above, there is a marked likeness to the Southern Harz type of the German deposits. The saline beds were evidently precipitated in a gradually subsiding lagoon which covered parts of Barcelona and Lerida in Lower Tertiary times.

The structure of the deposits makes their commercial development rather troublesome. At Suria[1] the beds turn steeply over in a monocline, the dip of which is about 70°. They are then again brought near the surface by a fault, from which the beds continue to dip in the same direction but at a much reduced inclination. At Cardona the deposits are worked in the axis of a steep anticline, where the continuity of the beds has been repeatedly broken by faulting. Here the chief potassium salt is sylvite, which occurs in nearly pure seams. At Suria, however, the salts are more varied. Certain bands consist dominantly of carnallite, but generally there is intimate admixture with rock-salt, and occasionally layers of sylvinite appear. Numerous potash zones, alternating with rock-salt, and of variable thickness and value, have been proved, the aggregate thickness being equivalent to 60 feet of carnallite and 13 feet of sylvite. The complete extent of the Spanish potash field has not yet been determined, but it has already been explored over a belt more than 6 miles long, and consequently very substantial reserves may be anticipated. The first large shaft sunk by the Franco-Belgian Syndicate, which has a concession at Suria, has now been completed, and it is expected shortly to raise 1,000 tons of raw salts per day. That production was not commenced during at least the last year of the war was due mainly to German intrigues and political troubles, the details of which need not here be discussed.

[1] E. M. Heriot, *Mining Journal*, vol. cxix, p. 753, December 15, 1917.

(*To be continued.*)

III.—Notes on Yunnan Cystidea. III. *Sinocystis* compared with similar Genera.

By F. A. Bather, D.Sc., F.R.S.

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(With Figures 22–30 on Plate VI.)

B.—Comparison with *Megacystis* (*continued*).

4. *The Thecal Openings.*

It is these which afford the justification for any comparison between *Sinocystis* and *Megacystis*. Those of *Sinocystis* are, it will be remembered (*antea*, December, 1918, p. 534), a transversely elongate peristome, a hydropore-slit approximately parallel to the peristome, a gonopore to the left of the anal plane, and a hexagonal or pentagonal periproct. These openings, though differing in details, are in number and position essentially similar to those of *Aristocystis*. Hitherto there has been much uncertainty as to the positions, and even the presence, of the hydropore and gonopore in *Megacystis*. It will here be shown that both are present, and that all four openings have much the same relations as in *Aristocystis* and *Sinocystis*, especially the latter.

(*a*) The Peristome and surrounding plates.

The shape of the peristome and the number and arrangement of the adoral plates are necessarily correlated with the number of brachiole-facets. Information on these points is forthcoming in regard to only 27 of the 48 named species; and even for these 27, intelligible drawings of the adoral region exist in the case of 15 at most. "Intelligible" is perhaps too favourable an epithet for some of these, but fortunately the British Museum specimens help in their interpretation.

The number of brachiole-facets varies from 3 to 5; being three in 2 species, four in 17 species, and five in 8 species, some of which are doubtful. It is clear from this, and still more from the numbers in actual specimens recorded, that four is the normal number of facets. The structure of specimens with that number will therefore be taken first.

Four brachiole-facets with a definite arrangement of adoral plates occur in the following British Museum specimens: E 7630–7637, E 7640, E 7642, E 7644, E 7645, E 7674, E 7677, E 16168, and E 16171, and probably also in E 7638, E 7643, and E 7676. There is a slight variation in E 7639, and a distinct difference in E 7673 (a pustulate form), which is the only other specimen that shows the structures in question.

In none of the British Museum specimens and apparently in none of those studied by other authors, with the doubtful exception of *H. gyrinus* Miller & Gurley (1894), have the cover-plates been preserved. Consequently the peristomial opening is clearly seen in most of the specimens (figs. 22, 24). In the normal form with four facets it appears quadrangular and somewhat extended transversely

to the anal plane. Removal of the infilling matrix shows that the quadrangular outline is furnished by a slight ridge which bounds the peristome and joins up the four brachiole-facets that lie one at each angle. The ridge on each side is frequently a little curved, with an adoral convexity, and it does not meet adjacent ridges, but merges into the margin of each brachiole-facet. Within this rim the surface slopes downwards to an elliptical margin, and thence passes vertically downwards as a tube of uncertain depth.

Just within the quadrangular rim the slope is generally indented by a slight rebate, and along this the inner side of the ridge is marked by a row of notches, irregular in shape and size, but generally appearing as vertical indentations with a rounded upper end. These no doubt bore a series of small plates that covered the peristome and subvective grooves, as in *Sinocystis*. The alternative suggestion that there were large tegminals, each attached by a toothed hinge, is opposed to the fact that no such plates have ever been found.

From the elliptical margin a narrow groove leads to each brachiole-facet, whence no doubt it continued on to the brachiole itself, as a subvective groove. No remains of brachioles have yet been recognized.

The thecal plates forming the margin of the peristome are six in number; of these there are two on the anterior margin, two on the posterior, and one at each side. The four subvective grooves lie on the sutures between these last and the adjacent plates. All these form Adoral circlet I, and may be called Adorals I (Ad. I).

Outside them comes Adoral circlet II, composed of eight plates (Adorals II, or Ad. II), namely, one supporting each brachiole-facet, and therefore corresponding with the sutures at the angles of the peristome, and four lying between these. The former four might be designated 'radials', and the latter four 'interradials'. Of the interradials, the two on each side butt on the right and left adorals of circlet I; the two that are anterior and posterior alternate with the paired anterior and posterior Adorals I, i.e. correspond with the anterior and posterior sutures.

This arrangement is shown in only two of Miller's figures, namely those of "*Holocystites*" *commodus* (our fig. 23) and *H. gorbyi*, which are probably synonymous. The figures of *H. parvus* and *H. scitulus* show the eight Adorals II, but in Adorals I the two posterior plates are not distinguished, and in the anterior interradius only one plate is drawn. Probably the structure was quite normal, though the two anterior Adorals I may conceivably have fused.

The peristome of *H. ornatus* was described by Miller (1878) as "surrounded by seven plates, and four (possibly five) arm bases". The figure, when interpreted by our present knowledge, shows that the Adorals I have been either not preserved or not distinguished, except in the case of the two posterior. Assuming the facets to be, as usual, on Adorals II, then there are, as usual, eight plates in that circlet. The specimen therefore is probably of the normal (Ad. I, 6; Ad. II, 8) type; no reason is given for supposing that it had more than four facets.

There are four other alleged species with four facets: *H. ornatissimus* (fig. 25), *H. papulosus*, *H. subovatus*, and *H. asper*. These are all pustulate forms, and the first three differ only in the number of thecal plates; there are 6 rows with intercalated plates in *H. subovatus*, 7 rows of unequally-sized plates in *H. ornatissimus*, and about 8 rows in *H. papulosus*. These differences, as we learn from *Sinocystis*, are only those of growth. The names are therefore synonymous and, since all were published at the same time (1891), the name *ornatissimus*, which comes first in the book, may be selected for the species. *H. asper* seems to have more tumid plates, and the periproct is elongate transversely, not diagonally as in the other forms. It may perhaps be a distinct species. The four drawings of the adoral surface agree so closely that they must be regarded as correct, at least in so far as what they show (fig. 25). The peristome has a thick rounded margin, and this probably represents Adorals I, though the component plates are not distinguished in the figures and indeed may have been fused. The outlines of Adorals II are distinctly drawn and show only six plates, namely four with facets on the right and left, one anterior, and one posterior. These two interradial Ad. II are elongate, especially the posterior, which is drawn as stretching from the elliptical periproct right up to the peristomial rim. In this feature *H. ornatissimus* and *H. asper* differ from the normal plan represented by *H. gorbyi* (fig. 23), but a more essential difference lies in the absence of the right and left interradials from Adorals II. The specimen which R. R. Rowley (1903, Greene's *Contrib. Indiana Palæont.*, i, p. 166, pl. xlviii, figs. 16–18) has referred doubtfully to *H. papulosus* probably does not belong to this species, since it has adorals on the normal *H. gorbyi* plan. It might be *H. ornatus*. There is in the British Museum no specimen on the *H. ornatissimus* plan.

We may pause here to compare the arrangement of the adorals in specimens with four facets with that in the earlier form *Sinocystis*, which also has four facets (*antea*, fig. 9, 1918, p. 535). The four facet-bearing plates in that genus are presumably homologous with the facet-bearing Adorals II of *Megacystis*. They appear, however, to form part of Adoral circlet I, and those on the right and left join each other as in the *ornatissimus* plan. On the other hand, there are two anterior and two posterior Adorals I, as in the normal *gorbyi* plan. It is possible that the right and left Adorals I are present but hidden by the cover-plates. In that case there would, as in *Megacystis*, be six Adorals I, forming a peristomial ring. The facet-bearing plates of *Sinocystis* would thus fall into place as part of Adoral circlet II, and the right and left Adorals II would be represented by the plates that alternate with them; but the remaining plates of circlet II are more irregular in size and position than in most (perhaps all) specimens of *Megacystis*.

The occurrence of five facets in *Megacystis* is clearly shown in S. A. Miller's figures of five species, but the arrangement of the adorals is not so clear. Applying to the figures the knowledge gained from the specimens previously discussed, we note that Adorals I (though doubtless present) are not represented for any of

these species except *H. splendens* Miller & Gurley (1894). In that species there are said to be 7 Adorals I, but the drawing shows 10. In the drawing (our fig. 28) the suture that should probably separate the two posterior adorals is not shown. If the figure be taken as roughly correct, then each pair of Adorals I enters into the proximal half of a facet; that is to say, the plates are larger than usual and so reach the actual facet. A similar arrangement is visible in specimen E. 7673 (fig. 29). In *H. splendens* the distal half of each facet is borne by an Adoral II alternating with the paired Adorals I. Between the five facet-bearing Adorals II are three interradial Adorals II, namely one posterior, one right postero-lateral, and one left postero-lateral. Thus this circlet, as drawn, has the normal number eight, and its difference from the four-facet plan is simply that the anterior Adoral II, instead of being an interradial, bears a facet. Circlet I, as drawn, owes the difference in the number of its plates (10 instead of 6) to the presence of interradial sutures in all interradii and not only in the posterior interradius. If those sutures were absent, the number and arrangement of the plates would be precisely as in the normal plan. Since Miller & Gurley say that the peristome is "surrounded with seven plates", it is possible that their drawing is wrong in this respect.

Miller's figure of *H. plenus* (1878) looks very different, but from his description it is obvious that the Adorals I enter into the facets in the same way as in *H. splendens*. The figure of *H. pustulosus* (1878) is so similar to that of *H. plenus* that the same interpretation of it seems legitimate. As to the number in each circlet, the evidence of these two species is unsatisfactory.

The drawing of *H. sphæroidalis* Miller & Gurley (1895) shows eight Adorals II, arranged as in *H. splendens*; but the drawing (our fig. 27) is so clear that it does not seem possible to suppose that Adorals I entered into the facets; they probably formed an inner, rather obscure rim. The original of *H. wykoffi* is crushed and in parts overgrown or missing; but it is easily interpreted on the lines of *H. sphæroidalis*.

Light is thrown on these specimens by the British Museum specimen E 7641 (fig. 26). This has been crushed along lines of weakness starting from the periproct and wandering towards the right anterior corner; thus some of the sutures in the adoral circlets are obscured. The specimen has been bored, during life, by some organism (possibly a bivalve mollusc) that has made round holes and caused a thickening of the test with obliteration of sutures. In addition the theca has been overgrown by bryozoans and one small pelmatozoan stem, probably after death, and the adoral region is much worn. One can, however, distinguish five facets, and a circlet of Adorals II arranged as in *M. sphæroidalis* (fig. 27). Indeed, a comparison of the two figures will show resemblances in such details as the irregular shape of the right posterior Adoral II, and the precise position of the facets on their respective plates—the anterior being approximately median, while those of the lateral pairs are shifted towards the adjacent interradials, so that the intervals between the facets are equalized. The importance of our

specimen, however, lies rather in the traces of Adorals I, which, as was surmised, form a narrow ring round the peristome. The sutures between them cannot be made out, but the number of plates cannot have been less than six or more than eight; six is the more probable.

Five facets are also said to occur in *H. baculus* Miller (1879), but the statement is not well substantiated by the figure, and is somewhat opposed by the description of the peristome as subquadrangular; Adorals I "are not clearly determinable"; if five facets were present the arrangement was probably as in *H. sphæroidalis*. The figure of *H. elegans* Miller (1878) is like those of *H. plenus* and *H. pustulosus*, but the holotype has been attacked by a boring-organism, so that its plates are anchylosed. In *H. perlongus* Miller (1878) the five facets are not clear in the figure, and there is a lack of detail.

The general conclusion to be drawn from the figures and descriptions of specimens with five facets is that they differ from those with four facets mainly in the presence of a facet on the anterior Adoral II and of a food-groove leading to it between the two anterior Adorals I.

Finally we come to the two species said to have only three arm-facets.

In "*Holocystites*" *amplus*, Miller (1892) mentions three facets on large bosses, and seems to imply that this is all by describing the peristome as in the centre of the triangle formed by them; but in the absence of a figure and of other details it is impossible to consider the case. Miller compares the species with *H. ventricosus* (1879), which is equally ill-defined, and may well be a synonym of *H. dyeri* (1879). *H. amplus* may therefore provisionally be regarded as based on either an imperfect specimen or an individual variation of *H. dyeri*.

The number three is also found in *H. gyrinus* Miller & Gurley (1894). The drawing of the adoral face (our fig. 30) shows apparently three facets corresponding to the left anterior, left posterior, and the united right-hand pair of the normal plan. The food-grooves leading from the two left-hand facets meet at what would in a normal form be regarded as the left end of the peristome. From this point a straight groove connects them with the right-hand facet. Thus the groove-system is roughly in the form of a ≻. These grooves are drawn of approximately equal width throughout, and, for the most part, with a structure that can only be interpreted as cover-plates. For these two reasons it is not possible to judge of the precise position or extent of the peristome, but the arrangement of the adoral plates suggests that it occupies about two-thirds of the stem of the Y measured from the fork. The length of this tract is about 9 mm., and the length of each food-groove is then also about 9 mm. The left posterior groove, however, is a little longer, perhaps as much as 11 mm., and it widens at its distal end as though it were forking. The left anterior groove has a slight curve, with the convexity on the left; and the stem of the Y is also slightly curved, with posterior convexity. The right-hand facet is

obscure, perhaps over-grown, for it may be mentioned that there are several cystid roots adherent to the specimen, as in *Sinocystis mansuyi*. The facets are, as usual, on Adorals II. Adorals I consist of the usual 2 posterior, 2 anterior, and 1 left; but on the right side, instead of the single adoral between two facets, there appear to be two adorals with the food-groove passing between them; thus there is the unusual number of seven Adorals I. Adorals II seem from the drawing to form a very irregular circlet of 10 or 11 unequal plates; the irregularity is greater on the right side.

Miller & Gurley's description does not altogether correspond with the preceding account based on their figure. This is due probably to the peculiar morphological views of S. A. Miller. They write (1894, p. 6): "On each side near the bottom of the ambulacral furrow there is a row of pores, but a free plate of the same character from the same or a similar species, when examined from below, does not show these pores in lines, nor can they be distinguished from the other pores that penetrate the plate from all sides. The ambulacral furrow, therefore, is not homologous with the ambulacral furrows of either crinoids or blastoids. There is no reason to suppose that it was a food-groove, was covered with minute plates, or was furnished with pinnules. It appears as a triangular furrow cut only half-way through the plates, and where following the suture lines of plates, the plates are more firmly joined than elsewhere by the denticulated edges, but when it enters upon a plate that bears an arm the furrow runs up to the base of the arm where it does not cut one-fourth of the thickness of the plate, and where the pores upon the sides appear to differ from the other pores that penetrate the plate only by being arranged externally in two lines." Of course the "furrow" is homologous with the food-grooves of all other Pelmatozoa, and there is every reason to suppose that it had cover-plates. Whether the cover-plates are preserved in this specimen or no is a different question. It is most natural to suppose that they have here been exceptionally preserved, just as they are preserved as a rule in the specimens of *Sinocystis*; further, as in some of the latter, there is a slight furrow between the cover-plates in some parts, as shown in text-fig. 10 and discussed on p. 535 (*antea*, 1918). The pores mentioned by Miller & Gurley are, no doubt, the diplopores, which are occasionally ranged alongside the food-grooves.

In specimen E 7673 (fig. 29) only three facets can be distinguished, but the arrangement differs from that of either of the two specimens just considered. The specimen is strongly pustulate and is crushed in the left-anterior–right-posterior plane; on the posterior half of the adoral face the intervals between the pustules were filled with a matrix not easily distinguishable from the stereom and removed only with difficulty; on the anterior half of the adoral face the plates are weathered and worn down. The facets preserved are the two on the left and the right posterior. Adorals I are 9 or 10, probably the latter. Two of these border each food-groove, and enter into the adoral half of the facet. That accounts for six plates. One Adoral I is in the posterior interradius, and three rather large plates are on the anterior border of the peristome. The adoral third

of the surface in the three anterior plates is marked with depressions at right angles to the peristomial border; they may be due to weathering, but even so the differential effect has to be accounted for. The middle one of these anterior plates has a further depression stretching along about three-quarters of the median line, or a little to the right of it. Since this depression starts from the fourth angle of the peristome, it may represent a much-worn facet. I am inclined to regard that as a correct interpretation, and, in that case, to consider the three anterior plates as compounds of Adorals II and I, the latter being represented by the depressed adoral tracts. This view makes the arrangement much more symmetrical and, but for the number of facets, very close to that in Miller & Gurley's figure of *H. splendens* (fig. 28), the general accuracy of which it thus confirms.

To summarize the facts concerning the adoral plates of *Megacystis*: In all species there are two circlets of adorals, Ad. I forming the peristomial rim and Ad. II bearing the brachiole-facets, normally four, sometimes five, and rarely (perhaps abnormally) three.

In the species with four facets two plans are distinguished. Of these the more common, exemplified by *M. gorbyi* and *M. commoda* (figs. 22, 23, 24), has Ad. I 6 and Ad. II 8. The four facet-bearing Ad. II are separated by four interradial Ad. II. The Ad. I are all interradial, two being posterior, two anterior, and one on each side. In the other plan, exemplified by *M. ornatissimus* (fig. 25), Ad. I are reduced in size, but probably remain six in number; Ad. II are only six, the two lateral interradials being eliminated.

In the species with five facets, Ad. II are eight as before, the difference being that the fifth facet is borne by the anterior Ad. II. In respect to Ad. I, these species show two plans of structure. In *M. sphæroidalis* (figs. 26, 27) Ad. I form a narrow rim, probably of six plates, as in *M. ornatissimus*. In the plan exemplified by *M. splendens* (fig. 28) Ad. I are enlarged so as to share in the facets, and seem to be 10 (or perhaps 11) in number, there being a suture in each interradius so that there are five pairs of adradial plates, with perhaps an additional posterior interradial. Specimen E 7673 (fig. 29) is, broadly speaking, built on this plan, but seems to have at most four facets; in other respects it resembles *M. splendens*. This suggests that the presence of a fifth facet may not be a truly specific character.

Of species with three facets, *M. gyrinus* (fig. 30) is the only one about which there is adequate information. The arrangement of the adorals round the single facet on the right is so irregular that one can hardly regard the form as normal. It does, however, differ from all the other species in the apparent cover-plates and the length of the tegminal food-grooves. The present comparative study at any rate shows that the three rays of *M. gyrinus* are not the primitive anterior, left, and right. In this connection it will also be remarked that the additional fifth anterior facet in some species of *Megacystis* does not correspond with the ray which the examination of *Sinocystis* led us to regard as possibly the primitive anterior, since that was the ray

here called the left anterior. This fact does not necessarily upset the hypothesis of a primitive tri-radiate form, but it suggests further research.

EXPLANATION OF PLATE VI.

Adoral Surfaces of Megacystis.

The drawings with numbers underneath are from specimens in the British Museum, and are of the natural size. Those provided with names are copied from Miller's original figures, and are presumed to be of the natural size. In all the drawings the details of ornament have been omitted, so as to emphasize the suture-lines and thecal openings.

Fig. 22.—E 7630. Hydropore distinct. Gonopore apparently with two openings near left post. facet.

,, 23.—*M. commodus*, after S. A. Miller, 1891, Advance Sheets 17 Rep. Geol. Surv. Indiana, pl. iii, fig. 2. The suture between the posterior Ad. I, here dotted in, is not shown in the original figure.

,, 24.—E 7631. Hydropore indicated by a faint dotted line. Gonopore on post. Ad. II.

,, 25.—*M. ornatissimus*, after S. A. Miller, 1891, op. cit., pl. v, fig. 2.

,, 26.—E 7641. Gonopore on post. Ad. II. Periproct crushed. Holes due to boring organism seen in N.W. quarter and a small pelmatozoan root on left interradial Ad. II.

,, 27.—*M. sphæroidalis*, after Miller & Gurley, 1895, Bull. Illinois State Mus., vii, pl. v, fig. 3. Ad. I not shown in the figure.

,, 28.—*M. splendens*, after Miller & Gurley, 1894, op. cit., v, pl. i, fig. 9. Suture between post. Ad. II not shown.

,, 29.—E 7673. The sutures between the posterior adorals are obscure.

,, 30.—*M. gyrinus*, after Miller & Gurley, 1894, tom. cit., pl. i, fig. 3. Hydropore low down on suture between post. Ad. I. Gonopore near base of left post. facet.

IV.—Drake's Island, Plymouth.

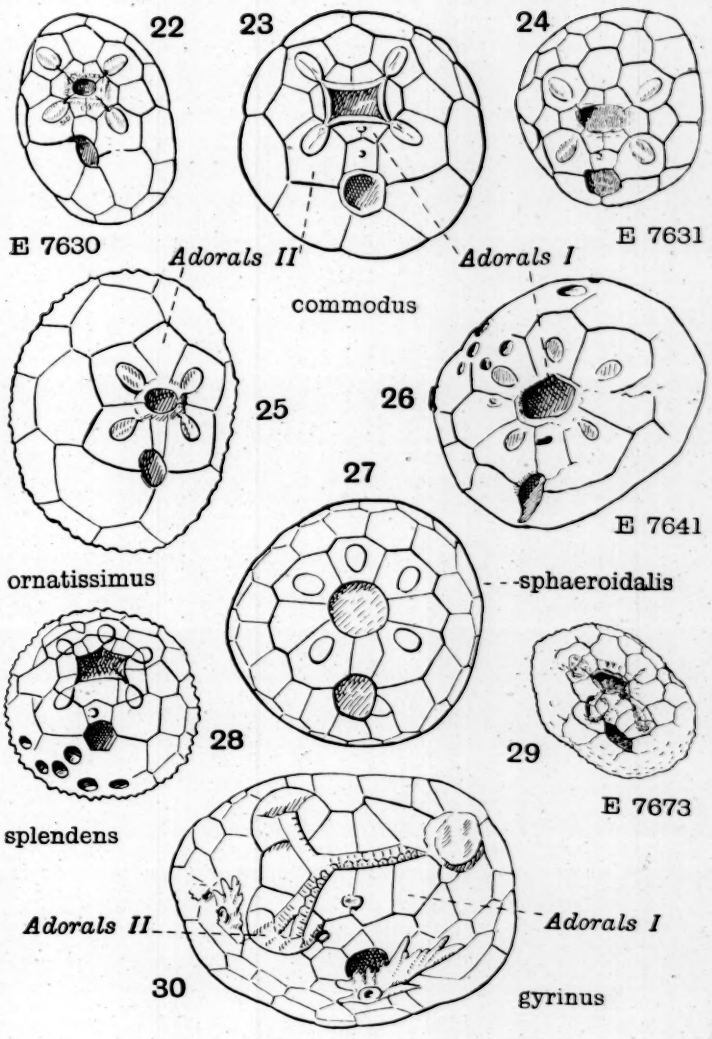
By E. B. Bailey, M.C., B.A., F.G.S.

THE main feature of the geology of Drake's Island is the association of volcanic rocks with marine limestone of Mid-Devonian age. The Geological Survey memoir[1] by Mr. W. A. E. Ussher attributes the discovery of the volcanic rocks to Mr. R. N. Worth. Mr. Ussher leaves their precise nature, "whether lavas or tuffs," somewhat in doubt, but states that they are "most certainly contemporaneous". As a matter of fact both lava and tuff occur, and are definitely distinguishable.

The limestones A and C of the sketch-map are attributed by Mr. Ussher to the Plymouth horizon, and the double outcrop is interpreted as a repetition due to plication. It is certainly possible that there is only one limestone—reduplicated by faulting—but I think it more probable that the limestone C is distinct from A, and is interstratified between the tuffs B and the lava D. At any rate the tuffs B are not very like the tuffs E, for they are much less distinctly bedded, and they much more commonly contain fragments of limestone.

On broadly based grounds of succession and structure, Mr. Ussher regards the Plymouth Limestone as older than the Drake's Island

[1] *The Geology of the Country around Plymouth and Liskeard*, 1907.

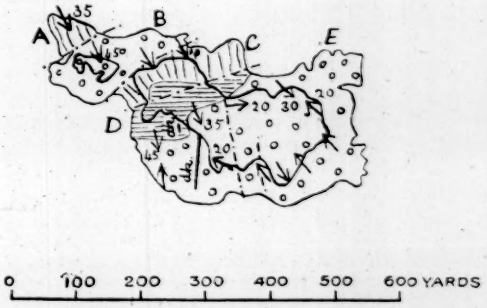


F. A. B. del.

ADORAL SURFACES OF *MEGACYSTIS*.

Volcanic Rocks. I have not found any evidence in Drake's Island bearing upon this point, and have therefore contented myself with a description of the rocks as they lie. If Mr. Ussher is correct, then the superpositions referred to presently are merely the result of inversion. All the rocks of the district, except the massive limestones, show a strong cleavage, so that there is no difficulty in admitting that such an inversion may exist.

My notes on Drake's Island were written down in the hope that they might be of value to those who make a study of the geology of the neighbouring mainland. During the winter 1915–16 I had several opportunities of going round the shores at low-water, so that it has been easy to clear up certain points, which have hitherto remained in doubt.



Map of Drake's Island, Plymouth.

Publication of a map of Drake's Island was forbidden so long as hostilities continued, and the resultant delay makes it possible to refer here to an important paper which has appeared in the interval. Mr. R. H. Worth,[1] a son of the late R. N. Worth, has given an account of the igneous rocks of Plymouth. It is true that our districts scarcely come in contact, since, while the War put one of us temporarily on to Drake's Island, it kept the other off; at the same time our subjects do seem to overlap, and it is only fair to state that Mr. Worth is of opinion that the so-called lavas of Plymouth are all intrusive, and that their associated fragmental rocks are intrusion-breccias. Experience of Drake's Island and a study of Mr. Worth's descriptions and figures do not tend to confirm this intrusion hypothesis. At the same time one cannot but welcome the additional data supplied in many particulars; and certain of his results will be made use of in their appropriate connection in the sequel.

A representative suite of specimens collected from Drake's Island is now in the possession of the Geological Survey (E 11402–11414). The lava D of the sketch-map is uniformly fine-grained,

[1] "The Dunstones of Plymouth and the Compton-Efford Grit": Report and Transactions of the Devonshire Association for the Advancement of Science, Literature, and Art, vol. xlviii, p. 217, 1916.

and its igneous structure cannot be made out with a pocket lens, though quite clear under the microscope. On the other hand, many of the fragments in the ashes B and E, especially E, when examined with a lens, show small felspars, set in a compact, sometimes almost flinty, base. These fragments have not uncommonly a well-marked fluxion structure, and under the microscope they look distinctly more acid than the lava D. All the igneous products of Drake's Island are very decomposed, with a plentiful development of albite, calcite, etc. In the tuffs, amygdales filled with albite, anorthoclase, and orthoclase, more particularly the first-named, occur in profusion. This feature is probably correlated with the comparatively acid nature of many of the enclosed fragments; the lava D was not closely examined for felspar-amygdales, but the similar rocks of the mainland[1] are seldom well endowed in this respect. The amygdales of the tuffs are interesting since they have in large measure resisted the Post-Carboniferous movement. At the same time it does not appear likely that the amygdales antedate the formation of the tuff, since the latter is itself cut by veinlets of alkali felspar. It is possible, however, that they formed before the tuff cooled.

Much the most peculiar rock on the island is an amygdaloidal limestone, closely mimicking a lava in appearance. A suggestion as to its origin is offered below (under C), where the various divisions distinguished by letters on the map are described *seriatim*.

Groups A–E.

A. Seventy feet of bedded grey limestone with some chert. The limestone does not appear very fossiliferous, but is so covered with barnacles that detailed examination is difficult.

Junction A B.—Fault.

B. One hundred and fifty feet of rather indistinctly bedded tuffs. These contain somewhat frequent lumps of limestone, and occasional separate corals, apparently blown into their present position.

Junction B C.—Probably a fault.

C. Fifty feet of limestone. The lower part has a little chert, and is well bedded and fossiliferous, consisting in some exposures of *Stromatopora*, with encrinites, etc. The upper part is practically unbedded, and is often very vesicular like a lava. The vesicles are filled, either partially or completely, with quartz and calcite, the former in finely crystalline aggregates. The appearance strongly suggests that this portion of the limestone was ejected as a hot bubbling calcareous ooze—a mud lava in fact.

Junction C D.—Very clear upward passage from limestone to pillow-lava exposed on south-west coast just north-west of a well-marked fault. The top of the limestone for a couple of feet serves as a matrix more or less completely isolating highly vesicular pillows of lava. The dip is very gentle.

D. Two hundred feet of lava. The lava (or lavas, if there is more than one flow) becomes compact a little above the vesicular pillowy base just described. The compact zone is of considerable thickness,

[1] R. H. Worth, op. cit., p. 225, pl. iii, fig. 13.

and is followed upwards by a mass of thoroughly vesicular lava disposed in rudely shaped pillows which are more or less separated from one another by chert rich in carbonate. The pillows only occasionally show a concentric arrangement of their vesicles.

The carbonate of the chert-carbonate rock just mentioned occurs as lenticular aggregates, sometimes showing, under the microscope, a dark centre, and also zones of growth marked by layers of dirt. It looks as if the carbonate had been precipitated first, followed by the chert. From analogy one may consider it possible that micro-organisms have played a part in the production of the deposit, though this is by no means certain. What I think is clear, is that the rock is in no sense a vein-stone. Mr. Ussher and Dr. Flett (op. cit., p. 83) have described a very similar chert from a quarry near Devonport Workhouse on the mainland. The Drake's Island chert weathers very readily to a soft rusty sponge through the removal of its carbonate crystals.[1]

Junction D E.—Upward passage from lava to tuff very well seen (though partially built over) in the cliff face of the south-west shore. The dip here is about 35°. Many local faults cross the junction; in fact, the whole of Drake's Island is cut up by small faults.

E. Two hundred feet of well-bedded tuffs.

Dykes cutting B, D, *and* E.—Four narrow dykes with rather conspicuous felspar phenocrysts have been traced for short distances through the volcanic rocks of Drake's Island and Little Drake's, though only two are shown on the sketch-map. They are for the most part two feet thick, and they share in the cleavage of the tuffs and lava through which they cut.

V.—The Mineral Composition of the Lower Greensand Strata of Eastern England.

By R. H. Rastall, M.A., F.G.S.

(*Concluded from p. 220.*)

6. Sandy.

THE well-known section alongside the Great Northern Railway just north of Sandy Station shows a total thickness of about 50 feet of ferruginous sands with occasional concretionary ironstone bands, resting on the Oxford Clay. This is therefore the lowest portion of the Lower Greensand. Numerous specimens from different levels in the exposure have been collected and examined, but they were all found to be very similar, and as a matter of fact not very interesting, so that a short description will suffice.

[1] Mr. Worth describes and illustrates additional occurrences of chert-carbonate rock from Plymouth; he regards the type as a product of the contact alteration of slate (op. cit., pp. 234–6, pl. iv, figs. 20–2). Professor T. J. Jehu and Dr. R. Campbell have found chert-carbonate rock among the fragments of a volcanic breccia on the border of the Scottish Highlands; "The Highland Border Rocks of the Aberfoyle District," Trans. Roy. Soc. Edinburgh, vol. lii, p. 183, 1917.

The only minerals occurring in abundance are zircon, kyanite, tourmaline, and staurolite, with small quantities of rutile and epidote and a few crystals of colourless amphibole and pyroxene. The zircons are quite normal and require no special remarks. Tourmaline is abundant and of many colours, including blue, green, olive-green, yellowish-brown, and brown varieties; the crystals vary a good deal in size and in degree of rounding, some being rather angular, while others are much rolled. Kyanite occurs in large blade-like crystals, often with very sharp edges, as well as in smaller and more rounded grains. Staurolite is unusually abundant in both large and small fragments, the smaller ones being as usual notably sharp and angular. Rutile and epidote are both rare, but of quite ordinary types, the former occurring only in small deep-red prisms. Several crystals of colourless pyroxene were easily identified by their high refractive index, strong birefringence, and extinction angles up to 40°. Some rather similar crystals with extinctions up to only 10° appear to be tremolite or some other amphibole.

As before stated, all samples contained a similar assemblage of heavy minerals, but it was noted that in some cases they were distinctly of larger size than in others. This is probably a process of natural sorting, correlated with varying strength of currents, rather than with any actual difference in the sources of the material itself. In such a notoriously current-bedded formation as the Lower Greensand this would naturally be expected to occur, and is evidently not of much significance.

7. Parish Sand Pit, Aspley Guise.

This pit, which is situated some 200 yards west of the church, is excavated in the lowest beds of the Greensand, as indicated by an examination of the neighbourhood and by the published 1 inch map of the Geological Survey (Sheet 46, N.W.). It shows about 30 feet of yellowish and greyish-white sand, very free from iron, and scarcely at all consolidated; near the top is a band of fullers' earth about 6 inches thick.

The process of separation was particularly easy owing to the small amount of iron present. When cleaned in the usual manner a sample of the unseparated sand shows fairly large grains of quartz of remarkably angular forms, together with a good deal of turbid felspar and a little glauconite. The shapes of some of the quartz grains are very curious, as may be seen from Fig. 5. These are, of course, specially selected examples and therefore not truly representative of the whole, but they are by no means the only peculiar forms present. Rounded and subangular grains of the type usually found in water-borne sands are quite uncommon.

The heavy minerals that sink in bromoform, though very abundant, are nearly always in quite small grains of very uniform size, averaging about 0·2 mm. in diameter, and very rarely exceeding 0·3 mm. The non-magnetic portion shows an unusually large number of mineral species. The most important are zircon, tourmaline, staurolite, kyanite, rutile, sphene, pyroxene, and

ilmenite. The most noteworthy and unusual feature is the presence of numerous crystals of sphene.

Sphene is quite abundant in crystals which are as a rule much rounded and chipped, but still show the characteristic lozenge shape. They are easily distinguished by their pale-yellow colour, very high index of refraction, which gives a broad black border, and very strong birefringence: crystals of the usual size generally give colours of the fourth order. Owing to the high refractive indices and strong dispersion the crystals when in the position of extinction between crossed nicols often show curious prismatic colours, which afford a useful indication of the mineral. Inclusions are very abundant, both circular bubbles of gas (or glass) and minute needle-like crystals. Fig. 6 shows a sketch of an unusually well-formed crystal of sphene, with both kinds of inclusions.

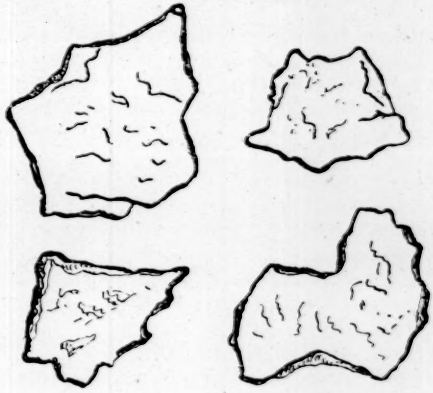


FIG. 5.—Quartz grains, Parish Sand Pit, Aspley Guise. × 50.

Rutile is also common in the usual red grains, generally much rounded and corroded. In a few crystals the colour is quite unusually deep. There are also orange or yellow crystals still sufficiently undamaged to show crystal-faces. Kyanite is abundant in large angular flakes and blades of quite normal character. Staurolite is very common in good-sized angular fragments of an orange-yellow colour. These need no special description. Tourmaline is fairly abundant, both the common brown variety in drop-like grains and in good crystals, together with a few more angular grains of an extraordinarily deep blue colour. Muscovite is very common in small flakes and a few broken crystals of pyroxene were also seen. The opaque iron ore is ilmenite. One very fine tabular plate with an etched surface shows the rhombohedral symmetry of the etched figures on the crystal faces.

Other samples taken from different parts of the same pit differ from the one described above chiefly in the much lower proportion

of sphene, together with a greater abundance of colourless pyroxene (diopside), which shows the characteristic jagged appearance of this mineral, due to the imperfection of the cleavage. Its maximum extinction angle is about 30°, and some care is needed to discriminate it with certainty from kyanite, which has about the same extinction angle. The well-marked transverse cleavage or parting of kyanite, parallel to c 001, will generally serve to distinguish them.

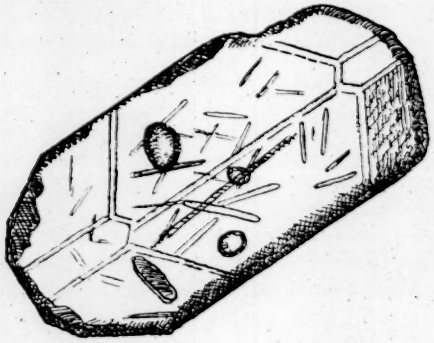


FIG. 6.—Sphene. Aspley Guise. × 300.

The most abundant heavy mineral is zircon; the crystals are often so sharp and well developed that the crystallographic characters can be determined and some of the angles measured approximately. The most common forms are 100, 110, 111, 001, 311 in various combinations, the usual ones being 110, 111, 311, and 100, 110, 111. The basal plane 001 is often well developed, apparently a somewhat unusual circumstance. The simple combination of a prism and pyramid 110 and 111 was also observed, though not frequently. According to Krushtchov the bipyramid 311 is specially characteristic of zircons in gneissose rocks, but rare or absent in those found in true granites. Both types are here almost equally plentiful. One small zircon was observed enclosing a minute but perfect crystal of sphene. Quite abundant also are well-rounded pink crystals with the optical properties of zircon and showing a well-developed zonary structure as figured by Krushtchov. It is still an open question whether these are zircon or xenotime, a mineral which is probably isomorphous with zircon and may even form mixed crystals with it. It is noticeable that in the pink crystals the tabular and rounded inclusions are less conspicuous than in the undoubted zircons and of a different type. The birefringence also seems to be slightly weaker; this is said to be characteristic of xenotime. There is also a pink mineral with slight pleochroism and birefringence higher than that of zircon. This commonly occurs as rounded grains with a curiously pitted surface. Those crystals which show prismatic forms are optically positive. Inclusions of any kind are rare. This is probably merely a variety of zircon.

8. A Small Exposure in a Cottage Garden by the Roadside, about half a mile west of Woburn.

This sample consisted of a dirty brown sand, containing much fine muddy material, and very ferruginous. The larger constituents showed no noteworthy features, and the heavy residue was quite small in amount. All the usual minerals were observed, namely kyanite, staurolite, rutile, tourmaline, and zircon, together with a good deal of magnetite and brownish opaque grains. None of these minerals showed any characters worthy of special description. It may be mentioned that the crystals of kyanite show the worn and rounded outlines usual in this district, while the staurolites also are more rounded than ordinary.

9. Leighton Hollow Wood, Woburn.

These specimens were collected from a long section by the side of the road from Woburn to Aspley Guise, and consisted of rather dirty ferruginous sands, which when cleaned, panned, and separated yielded some good specimens of heavy materials. As usual the chief species present were zircon, kyanite, staurolite, tourmaline, and rutile.

Zircon is very abundant as small, well-rolled grains, mostly as the clear colourless variety without zones, but showing characteristic inclusions.

Tourmaline is very common, chiefly as well rounded drop-like grains of an olive-green or brown colour, but other grains are distinctly blue. One in particular showed a peculiarly intense and brilliant blue shade, while in others the same tint is less marked. Kyanite shows many good examples of the most characteristic forms, some fairly sharp, while others are a good deal rounded.

Staurolite is found in grains showing a wide range of forms: while some are very angular indeed, others are unusually well rounded, and many transitional types are seen. The orange-red variety of rutile is the more common, sometimes in fairly large and irregular pieces, but there are also a few large crystals of a deep blood-red colour. Epidote is a rather rare constituent, generally in rounded green grains, but occasionally in large angular pieces. Although this locality is so near Aspley Guise no sphene was found, a rather remarkable circumstance.

10. Small Pit by Side of Road between Woburn and Little Brickhill.

This is a small excavation about 5 feet deep, in fine incoherent yellow sand, with a few brownish streaks and patches. The sand is of uniform grain, nearly all passing through a sieve of about 1 mm., and there is very little fine mud on washing, hence the grains must be naturally well-graded.

A small sample, strongly heated in a crucible for some time, turned to a bright brick-red colour, presumably from dehydration. Another sample boiled for some time with acid and well washed showed a large amount of bright-green glauconite, and also some grains, similar in size and shape, but of a pale-brown colour. As this seemed a favourable opportunity to investigate the nature of these

grains, they were separated as well as possible by washing in a flat dish and mounted in Canada balsam in the usual way for microscopic examination. The grains vary much in colour, showing many shades of green, also pale brown and nearly colourless. Those with the smoothest surface and least appearance of corrosion show the brightest green colours, while the brown and white grains are obviously altered grains originally green; all intermediate stages can be seen. Some grains are yellowish brown by transmitted and green by reflected light. It was not possible to determine whether the white or the brown grains represent the greater degree of alteration. When small, the brown, and more particularly the white, grains show a peculiar mottled depolarization effect. Some of them show a curious resemblance to grains of turbid felspar, and the discrimination is not always easy. However, the felspars generally show a definite extinction, which the others do not. The most interesting feature of these grains, however, is their form. Many of them have peculiar curved, nodular, or botryoidal outlines, and often a distinctly globular centre. A careful examination of a large number under high magnification, up to 100 diameters, goes far to confirm the idea that many grains of glauconite are in fact casts of the chambers of Foraminifera, while the brown grains so common in the Lower Greensand in surface exposures and shallow pits are undoubtedly formed by oxidation of the green grains of glauconite. This process of change so greatly increases the density of the grains, by the elimination of their lighter constituents, that many of them sink in bromoform until the outer weathered skin has been dissolved away by acid.

The quartz grains in this specimen show some remarkable features; they are specially notable for their angularity and very irregular shape. A few are subangular, while really rounded grains are rare. The average size of the quartz grains is about 0·3 mm. One or two grains contain a few small needles of rutile, the so-called sagenitic quartz, but after prolonged search the presence of tourmaline needles could not be established. Felspar is very abundant, in white or pale pinkish grains; most of them are orthoclase, but microcline was also seen, and a few grains of plagioclase, with extinction angles up to 30°. It was estimated that quartz is the most abundant mineral, making up perhaps half of the total, and that felspar and glauconite are in about equal amounts, while other minerals of any considerable size are scarce: a slide mounted from material without previous separation showed only one crystal of rutile and one or two flakes of muscovite.

The heavy minerals from this locality are of special interest, since they are abundant and in great variety. The most important minerals quantitatively are kyanite, staurolite, rutile, tourmaline, zircon, and iron ores, but, as will be noted in due course, several rarities are found. It is, however, less confusing and better to treat these separately, together with any notable peculiarities of the commoner minerals.

Kyanite is abundant in large thick tabular and blade-like crystals, most of them being distinctly rounded and rolled (Fig. 7). Nearly all of

them lie on the cleavage parallel to 100, and therefore show a constant extinction angle of about 30° and the emergence of a negative bisectrix. Staurolite is unusually abundant, in crystals of all sizes, some being as much as 0·3 mm. in diameter: the crystals are nearly always angular and shapeless, very few showing any traces of crystal forms. The colour is always orange-yellow and the pleochroism distinct (pale yellow to orange). Rutile is extraordinarily abundant, both in good crystals and in shapeless grains of all sizes. The colour also varies remarkably, from quite pale yellow to the deepest crimson red with submetallic lustre. The presence of brookite was suspected, but has not been confirmed. Tourmaline is in crystals of various sizes and shapes, but not very abundant. The majority are of a brown colour and much rounded, more angular blue grains being rare. Zircon is numerically the most abundant of all the heavy minerals, and some

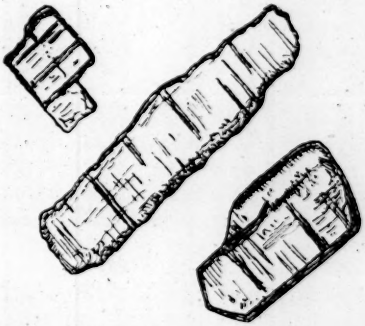


FIG. 7.—Kyanite crystals, near Woburn. × 100.

crystals are unusually large, up to 0·2 mm. in length and 0·1 mm. in breadth; the majority are much smaller than this. The number of different varieties observed is great, and the variation very wide. Black and brown iron-ores are plentiful, but in no way remarkable. Muscovite is abundant in minute flakes.

The slides made from this material present several features of considerable mineralogical interest: apart from the great abundance and variety of the zircons as before mentioned, there are also several good examples of twin-crystals of rutile of various types, especially "elbow twins". In a curious flat tabular twin of this kind, the angle between the two portions is about 120°. As the crystal does not lie quite flat the angle cannot be determined with great accuracy, but the twin clearly belongs to the e (101) type, the commonest law in this mineral. As shown by reflection in incident light the large faces of both individuals are exactly co-planar. The flat tabular form is not common in this mineral, and suggests that the crystal developed between the foliation-planes of a schistose rock. Another elbow twin is remarkable in that one individual shows in addition lamellar twinning, apparently on the same law. This crystal is pale yellow in colour. A small and very irregular fragment also shows

an immense number of closely set twin-lamellæ: the law in this case is indeterminable.

Among the rare minerals may be mentioned a single subangular grain of garnet, with unusually rounded contours and smooth surface. This must have undergone an immense amount of attrition during a prolonged period and has doubtless been derived ready-made from some older rock, since such a degree of smoothness is very unusual in this mineral. Two good-sized grains of a brown mineral are of much interest, since they are probably cassiterite. The most notable characters are the pleochroism, red to greyish brown, and the very numerous twin-lamellæ, so characteristic of the cassiterite in Devono-Cornish granites. Sphene was not found, though a prolonged search was made for it during several hours.

Summary and Conclusions.

Although it is obvious that much more detailed work would be required before any positive deductions could be drawn from the facts here set forth, nevertheless certain interesting features present themselves and may be briefly summarized here. In the first place, although the general mineral assemblage shows great similarity throughout the whole stretch of country yet examined, being characterized everywhere by zircon, kyanite, staurolite, tourmaline, and rutile, there are certain distinct local differences. In Norfolk we find in fair abundance garnet and blue soda-amphibole, and these appear to extend as far as Ely. Further west than this the amphibole is non-existent and garnet is exceedingly rare, having been observed at two localities only in the minutest quantity. Green mica was also observed only in the Sandringham Sands. Again in Norfolk most of the heavy minerals are distinctly larger than further to the west and some of them more angular. These facts taken together, and especially the presence of blue amphibole, suggest derivation from the north-east, possibly from Scandinavia.

Further to the west a different assemblage of accessory minerals appears to set in, such as colourless pyroxene and green epidote, with curious pinkish zoned crystals usually attributed to zircon. Here also deep-blue tourmaline seems to be more common, though it is not confined to this neighbourhood. But perhaps the most noteworthy mineral of the western area is sphene; this is local in its distribution: although it was observed at Great Gransden, it is really common only at Aspley Guise. It is also of some interest to note that some grains believed to be cassiterite were seen only in the extreme west, near Brickhill. If the presence of this mineral in any quantity could be established with certainty a south-western origin for the material could be regarded as established. This point needs further investigation.

Thanks are due to Professor Bonney for the kindly interest that he has shown during the progress of the work and for opportunities of examining specimens in his collection for purposes of comparison; also to Mr. W. H. Wilcockson for help in the field and laboratory in 1914.

VI.—On a Scandinavian Erratic from the Orkneys.

By Instructor-Lieutenant W. I. Saxton, B.A., R.N., and
Lieutenant A. T. Hopwood, R.A.F.

THE general behaviour of the Scandinavian ice-sheet which spread over the North Sea at the climax of the Glacial period is fairly well known. Numerous erratics show that it reached the coast of Yorkshire and the eastern counties of England. Farther north no erratics have been found, but Dr. Jamieson[1] and others have shown that it approached the coast of Aberdeen. Dr. Croll[2] and Drs. Peach and Horne[3] have shown that it forced the Scotch ice flowing eastward from the Moray Firth to turn in a northerly and north-westerly direction across the northern part of Caithness and over the Orkneys. They concluded that ice from the Christiania district must have passed a few miles to the north of the Orkneys. This is well shown in the chart attached to their paper and also in Professor James Geikie's[4] map. The occurrence of a few Scandinavian erratics in the Orkneys would confirm these deductions. The only erratic recorded from Orkney which may be of Scandinavian origin is the Saville boulder described by Professor Heddle,[5] Drs. Peach and Horne, and Dr. J. S. Flett.[6]

The rock which it is the object of this paper to place on record was found between Quoy Ness and Stanger Head on the eastern shore of Flotta—a small island at the southern entrance to Scapa Flow. Several boulders were found, one of which was nearly a foot in diameter. Specimens were examined by Dr. Flett, who describes the rock as follows: "It is of grey colour with black spots of ferruginous minerals, and the felspar which is its principal component has the simple twinning, elongated form, and blueish shimmer that characterize the holocrystalline rocks of the laurvikite series.

"In microscopic section it proves to be a 'laurdalite',[7] as shown by the following characters: The felspars are natron-microcline (soda-orthoclase or anorthoclase), with the types of inclusions known in laurdalite. Nepheline is fairly abundant, often in pegmatitic intergrowth with felspar. The principal ferromagnesian mineral is a violet or greenish-violet augite, in which diallage structure and schiller inclusions may frequently be noted. A bright green pyroxene (ægirine or ægirine-augite) is also not uncommon. Black mica (lepidomelane) is frequent. Hornblende (barkevikite) in

[1] Thomas F. Jamieson, "The Glacial Period in Aberdeenshire and the Southern Border of the Moray Firth": Quart. Journ. Geol. Soc., vol. lxii, p. 13, 1906.

[2] Croll, "The Boulder-clay of Caithness a Product of Land Ice": Geol. Mag., Vol. VII, pp. 209, 271, 1876.

[3] B. N. Peach & John Horne, "The Glaciation of the Orkney Islands": Quart. Journ. Geol. Soc., vol. xxxvi, p. 648, 1880.

[4] James Geikie, *The Great Ice Age*, 3rd ed., 1894.

[5] Heddle & Forster, *Min. Mag.*, vol. ii, p. 174.

[6] J. S. Flett, "On Scottish Rocks containing Orthite": Geol. Mag., 1898, p. 388.

[7] W. C. Brögger, *Die Eruptivgesteine des Kristianagebietes*. III. Das Ganggefolge des Laurdalits. Kristiania, 1898.

small amount; comparatively large prisms of apatite are numerous. The rock is very fresh; it shows in places a well-marked protoclastic structure, and there is a tendency to the formation of reaction rims around clusters of pyroxene. The minerals and the structures of this rock accordingly enable us to identify it beyond question with the laurdalite of the Christiania district."

Foreign erratics are not uncommon on the shores around Flotta. They are the typical erratics of the Orkney boulder-clays, and have mostly been derived—as shown by Drs. Peach and Horne—from the Moray Firth area. The association of the laurdalite with these rocks is evidence that it is of the same glacial origin. The alternatives to transport by glacial ice are transport by floating ice or transport by a ship as ballast. The first is rendered improbable by the fact that floating objects in the Kattegatt drift to the north along the Norwegian coast.

Although a close connexion formerly existed between the Orkneys and Scandinavia, there is but little likelihood of a ship coming to Flotta, for it is a very unimportant island. If a ship came there she would use the harbour of Pan Hope near by, and not the open shore, and would probably take in rather than discharge ballast. The warships of the Norsemen frequented Scapa Flow, but the same remarks are true of them, for they went to the northern side of the Flow. There is, then, no reasonable doubt that it is a true glacial erratic, and as such it confirms the accuracy of the track of the ice as shown in the glacial maps, and is of interest as being the first undoubted Scandinavian erratic found in Scotland or in the Orkneys and Shetlands.

In conclusion, we wish to express our thanks to Dr. Flett for more than encouragement in preparing this paper.

REVIEWS.

I.—The Geological Aspects of the Coral-reef Problem. By W. M. Davis, Ph.D., Sc.D. *Science Progress*, vol. xiii, pp. 420–44, 1919.

For some years past Professor W. M. Davis has been engaged in a detailed study of the old problem of the origin of coral reefs, in the light of the new material accumulated by many observers, both European and American. As he very justly points out in this paper, the problem is mainly geological, whereas the majority of writers have regarded it chiefly from the biological standpoint, without a proper appreciation of the geological significance of the facts observed by them, and what is perhaps of still greater importance, the meaning of certain facts that they failed to observe. According to him the most significant of these facts are the embayment of the shore-lines of islands encircled by barrier reefs and the existence of unconformable contacts of reef and lagoon limestones with their foundations. In the past attention has largely been directed to atolls, where it is obvious that neither of these features can be observed, but they undoubtedly have a considerable bearing on

the origin of these, as well as of reefs with central islands and of raised reefs of all kinds. Professor Davis concludes definitely that both these features are inconsistent with the formation of reefs during still-stand conditions or elevation, and that all the evidence is strongly confirmatory of Darwin's original view of reef-building during subsidence or submergence.

Furthermore, a distinction must be drawn between the two effects just mentioned: the drowning of an island, with embayment of the coast, may be brought about by a relative rise of the sea-level brought about by elevation of the sea-floor elsewhere, or by the setting free of water from an ice-sheet, as elaborated by Daly in the theory commonly known as "glacial control". Professor Davis does not consider, however, that either of these processes have played a large part in the production of coral-reefs; he believes that actual subsidence, in many cases of a local nature, is the dominant factor, while the raised reefs must obviously owe their present position to uplift, which also is frequently limited to comparatively small areas, and is sometimes referable to tilting of island groups.

One of the most significant structural features of coral reefs is the usually well-marked "unconformable" contact of reef and limestones with their foundations, the word "unconformable" being here used to mean inclined, while "conformable" means that the base is horizontal. This feature has been neglected by the great majority of writers, many of whom were not geologists. A careful examination of many such contacts, where visible in raised reefs, has shown in nearly all cases pronounced erosion of the underlying, usually volcanic rock, amounting in some cases to 600 or 800 feet. This sloping contact with the eroded surface below is inconsistent with formation of reefs on wave-worn submarine platforms, according to the Rein-Murray theory. Even the reefs around the granitic islands on the Seychelles bank may be assumed to possess unconformable contacts, since they clearly rest on sloping granitic spurs, indicating deep erosion and embayed coastlines. It follows, therefore, that here also there must have been submergence.

The general conclusion reached by Professor Davis is that in the great majority of cases the features exhibited by fringing and barrier reefs can best be explained on the hypothesis of their formation during subsidence. The downward movement is not necessarily continuous; in fact, it is clear in many cases that it was intermittent and occasionally reversed, and a wide field is thus allowed for local variations. The problem of atolls now at sea-level is on a somewhat different footing, since the facts are less accessible to observation, but by analogy the same line of reasoning can be applied. The recent work of Foye on the Fiji group is confirmatory of the general ideas here put forward, and this most important paper must be regarded as a step forward in the rehabilitation of Darwin's theory, which has of late years been more or less under a cloud, but is now apparently destined once more to hold the field as the orthodox solution of this difficult but most interesting geological problem.

II.—Subsidence of Reef-encircled Islands. By W. M. Davis. Bull. Geol. Soc. Amer., vol. xxix, pp. 489–574, 1918.

SINCE the preceding review was written, another and much longer paper of earlier date has come to hand, in which Professor Davis enunciates in greater detail, with more numerous figures, the views summarized above. He also pays more attention to the negative evidence, as shown by the absence of reefs on coasts of emergence or in areas where their growth is prevented by accumulation of detrital deposits on a large scale. The reefless coast of Madras, which has risen from the sea, is contrasted with the half-submerged cliffs of the north-east side of New Caledonia, now bordered by fringing reefs, with a barrier reef 5 to 10 miles off the shore. Stress is also laid on the unequal depths of lagoons and banks, which are inconsistent with the requirements of the glacial control theory, and several pages are devoted to a discussion of the origin of atolls. The conclusions to be drawn from the Funafuti and Bermuda borings are briefly summarized, and it is pointed out that information as to the depth of atoll-lagoons is still far from complete. Professor Davis believes that Darwin's theory of intermittent subsidence affords the most satisfactory explanation of atolls as well as for the other types of reef. He also considers that Molengraaf's theory of volcanic subsidence, while not proved to demonstration, is a contribution of much value to the solution of the reef problem. An extensive bibliography is appended to the paper.

III.—The Antiquity of Parasitic Disease.

On the Parasitism of Carboniferous Crinoids. By Roy L. Moodie. Journ. Parasitology, iv, pp. 174–6. June, 1918.

MR. MOODIE means "parasitism *on* crinoids" or what our scientist-stylists would call "the parasitization of crinoids". He has found in America (North or South; locality not given) in some Carboniferous rocks of age not stated (though Keokuk is alluded to), crinoid stems swollen in reaction to the attacks of a parasite, similar to those described by R. Etheridge fil. (1879, Proc. Nat. Hist. Soc. Glasgow, iv, pp. 19–36). Mr. Etheridge quoted descriptions by previous authors, but was the first to assign the phenomena to their true cause, and (*pace* Mr. Moodie) to determine the parasites in several instances. Von Graff (1885) compared these swellings, as well as others in Mesozoic crinoids, to those due in recent crinoids to the attacks of *Myzostoma*, but he did not prove this by any discovery "of the carbonized remains of" a myzostomid, as Mr. Moodie states. Mr. Moodie claims that the stems at his "disposal are the first to be recognized in America as in many ways suggesting parasitism". He should look at Wachsmuth & Springer's *Crinoidea Camerata of North America* (1897), p. 43, pl. i, fig. 2; also p. 502, pl. xxxix, fig. 7, which shows swellings on the arms of an *Agaricocrinus* much more like myzostomid cysts than anything figured by Von Graff.

Mr. Moodie's "interest in these objects is due to the fact that the [Carboniferous] swollen stems must be regarded as the first evidences of disease in geological history". This is not quite correct. A number of the thecas of *Holocystites* (=*Megacystis*) from Indiana, described by S. A. Miller, present circular depressions plainly due to the attacks of some boring organism, and as a result the component plates are usually anchylosed and swollen (see fig. 26 of my "Notes on Yunnan Cystidea" now appearing in this Magazine). Mr. Moodie will also find a description and figures of a stem of *Botryocrinus ramosissimus* with small pittings, apparently the work of parasites, accompanied by swellings and by a curious breaking-up of the columnals, in "Crinoidea of Gotland" (1893, Svensk. Vet.-Akad. Handl., Bd. xxv, No. 2, p. 120, pl. vi, figs. 174–8). Plate lxxiv of the Crinoid volume in Barrande's *Système Silurien de Bohême* (1897) represents several swollen stems from bed f. 2 of Konieprus. All these instances are of Upper Silurian age.

If nothing of the kind has hitherto been recorded from Ordovician or older rocks, this is due, at all events for our country, to the greater rarity of crinoid-stems and to their less frequent preservation as calcified fossils. It must not be inferred that the Ordovician or Cambrian were golden ages free from disease. Indeed, among stem-fragments from the Upper Ordovician Rhiwlas Limestone of Llwyn-y-Ci, north of Bala (Brit. Mus. E 21503) is one that is slightly swollen and shows traces of boring; a similar fragment less clearly preserved comes from the same or a slightly lower limestone at Glyn Ceiriog (E 21495). Anyone with time to search our museums would probably find further examples.

F. A. Bather.

IV.—Descriptions of some Queensland Palæozoic and Mesozoic Fossils. By R. Etheridge, Jun. (1) Queensland Lower Cretaceous Crustacea; (2) Additional evidence of the largest Australian Permo-Carboniferous Trilobite; (3) A Remarkable Univalve from the Devonian Limestone, Burdekin; (4) *Vetofistula*, a new form of Palæozoic Polyzoa, Reid's Gap. Geol. Survey of Queensland, Pub. No. 260, pp. 26, with 3 pls., 1917.

(1) The Brachyuran *Prosopon etheridgei*, H. Woodward, is redescribed from specimens showing portions of the chelipeds and ambulatory limbs as well as the abdominal somites and telson. *Hoploparia mesembria*, n.sp., is described from a portion of a carapace and six abdominal somites. *Glyphæa arborinsularis*, n.sp., is based on one fairly complete and one imperfect carapace, and a third specimen showing the abdominal somites and portions of appendages. An imperfect cheliped is referred with doubt to the genus *Callianassa*. The illustrations, reproduced from photographs, give an excellent idea of the general appearance of the specimens, but a few line drawings would have greatly assisted their comprehension.

(2) Portions of a trilobite, of which the total length when complete must have been about 60 mm., are referred to the species previously described by the author as *Phillipsia grandis*, the generic reference being only provisional.

(3) *Polyamma burdekinensis*, n.g. and n.sp., is compared with the Canadian Silurian *Helicotoma* (?) *spinosa*, Salter, and with Triassic and Silurian species referred to *Cœlocentrus*, Zittel, but as the single specimen does not display the characters of the aperture and base its systematic position is left undetermined. The figures are "a trifle larger than natural size", but the exact dimensions of the specimen are not given.

(4) *Vetofistula mirabilis*, n.g. and n.sp., from the Middle Devonian, is compared with *Rhabdomeson*, Young & Young, and *Chilatrypa*, Ulrich, and is provisionally referred to the family Rhabdomesontidæ, and still more hesitatingly to a sub-family for which the name Vetofistuliporidæ (*sic*) is proposed.

V.—Revision of some Phacopid Genera. By F. H. McLearn. *Ottawa Naturalist*, xxxii, pp. 31–6, 1918.

SEVERAL genera of the Phacopid Trilobites are re-defined and their phylogenetic relationships are discussed. *Dalmanitina*, Reed, is extended to include a series of generalized forms extending from the Ordovician through the Silurian. In the Devonian this line gives rise to species forming the genus *Phacopina*, J. M. Clarke, which, however, does not belong to the sub-family Phacopinæ but to the Dalmanitinæ. The Phacopinæ originated at the beginning of the Silurian as an offshoot from the primitive line, and gave rise to two stocks. One of these forms the genus *Phacops*, s.str., of wide distribution in the Silurian and extending into the Devonian; the other, *Phacopidella*, Reed, is confined to the later Silurian of Bohemia.

VI.—The Phylogeny of the Acorn Barnacles. By Rudolf Ruedemann. Proc. Nat. Acad. Sci. Washington, iv, pp. 382–4, 1918.

Possible Derivation of the Lepadid Barnacles from the Phyllopods. By John M. Clarke. T.c., pp. 384–6.

ONE of the most characteristic features of the Cirripedia is the possession of an armature of shelly plates developed by the calcification of separate areas in the "mantle", which represents the shell-fold or carapace of other Crustacea. It is characteristic of, but not peculiar to, the Phyllocarida that certain portions of the carapace are separated by suture-lines—a movable rostrum in the recent forms and an additional dorsal plate in certain fossil genera. With little more than these facts to go upon, Mr. Ruedemann endeavours to show that the Cirripedia, and in particular the sessile or operculate forms, have been derived from the Phyllocarida. He mentions an undescribed genus, *Eobalanus* (no specific name is given), from the Upper Ordovician, in which the form of the five pairs of lateral compartments suggests a bivalved carapace, and he ingeniously compares this with the carapace of certain Devonian Phyllocarida. As in many fossil Cirripedia, the opercular valves, scuta and terga, have been lost, and these valves, the most persistent of all throughout the group, are neglected in Mr. Ruedemann's

morphological speculations. Apart from this, however, there are many difficulties in accepting the derivation of the Cirripedia here suggested. The recent Phyllocarida are, beyond a doubt, members of the sub-class Malacostraca, and it can only lead to confusion if they are grouped under the Phyllopoda. There is no hint of affinity with them in the structure of recent Cirripedia. They differ widely in the regions of the body, the structure and grouping of the appendages, and the position of the genital apertures. The resemblances which Mr. Ruedemann has to set against these differences are trivial and far-fetched. It is possible that the Cirripedes have been derived from Phyllocarida, but Mr. Ruedemann does not convince us that it is probable.

Mr. J. M. Clarke, accepting Mr. Ruedemann's hypothesis with regard to the sessile barnacles, tries to show that the pedunculated forms were independently evolved from the Phyllocarida by way of the obscure genera *Lepidocoleus*, *Turrilepas*, and *Strobilepas*. If these genera are Cirripedes at all, which, according to Withers, is more than doubtful, their connexion with the normal Pedunculata has still to be elucidated. If the latter have been evolved independently of the Operculata from ancestors that were not Cirripedia, the resemblances between the two groups go far beyond any case of convergence hitherto recognized.

Phylogenetic speculations are of value in proportion to the extent and importance of the facts on which they are based. In these two papers the foundation appears altogether inadequate to sustain the superstructure.

W. T. C.

VII.—A Century of Science in America, with Special Reference to the *American Journal of Science*, 1818–1918. Edited by E. S. Dana. pp. 458, with 22 portraits. Yale University Press, 1918. $4.

THIS handsome volume is published in commemoration of the centenary of the founding of the *American Journal of Science* by Benjamin Silliman in July, 1818. Some of the chapters were based on a series of seven Silliman Memorial Lectures, and the whole cost of publication has been defrayed from the income of the Silliman Memorial Fund. As might naturally be expected, therefore, the subject-matter is very largely geological and mineralogical, but some 150 pages are occupied by chapters on the progress of chemistry, physics, zoology, and botany, each contributed by a specialist in his own subject. The first chapter, by the editor, details at some length the history of the *American Journal of Science* and the gradual evolution which it has undergone, from its earliest beginnings as a magazine of science, agriculture, and the arts, to its present rather specialized form, in which geology and mineralogy are dominant. It is shown that its foundation marks the beginnings of active scientific research on modern lines in the United States, and its progress is coeval with the extraordinary development of science in that country. The other chapters are written by men of light and leading in their respective spheres, and give admirable

summaries of the history of the various branches of geology and mineralogy in the last hundred years, mainly from the American standpoint, but still with complete acknowledgment of the value of work done in other countries. Of special interest, because somewhat novel, is the chapter entitled "A Century of Government Geological Surveys" by Director George Otis Smith, giving a detailed account of the beginnings and subsequent progress of that vast organization known as the United States Geological Survey, which has accomplished such wonders in the exploration and development of the resources of the country. This book leaves on the mind of the reader a feeling of admiration at the many-sidedness, activity, and originality of geology and the allied sciences in America at the present time.

VIII.—Ore-deposits of the Boulder Batholith of Montana: a Genetic Description. By P. Billingsley and J. A. Grimes. Trans. Amer. Inst. Min. Eng., vol. lviii, pp. 284–361, 1918.

At the present time the State of Montana is the most important producer of copper in the world, and the geological relations of its deposits are naturally of the utmost interest. In this paper the authors show in the clearest possible manner the intimate relation that exists between orogenic movements, igneous activity and mineralization. The main folding of the Rocky Mountains, in the Middle Cretaceous, was followed by andesite eruptions in the Upper Cretaceous; and this again by extensive thrust-faulting. The intrusion of the main batholith probably took place in the Eocene, while normal faulting, accompanied by rhyolite flows, extended from the Oligocene to the Pliocene. The intrusion of the batholith, here called the granite stage, is divided into four phases: (1) basic diorite and pyroxenite, (2) quartz-monzonite (the main mass), (3) aplites and pegmatites with tourmaline and other pneumatolytic minerals, (4) quartz porphyry with metalliferous quartz-veins. The mineralization belonging to the monzonite phase is mainly associated with outlying bosses or cupolas rather than with the main intrusion: it includes auriferous pyrrhotite, pyrite and magnetite, as disseminations and contact deposits, the latter also bearing copper and bismuth: the fissure veins also contain copper, zinc and lead: in many localities secondary enrichment is important. The veins of the aplite and pegmatite phase carry galena, blende, chalcopyrite, pyrite, arsenopyrite and rhodochrosite. The final quartz-porphyry phase gave rise to very rich copper deposits with enargite, tennantite, tetrahedrite, bornite, covellite and chalcocite; these are mostly rather deep within the batholith.

The earlier andesite stage gave rise to deposits of native copper, magnetite and galena with gold and silver, while the later rhyolite flows are accompanied by gold veins with little sulphide. It is shown that the greater part of the mineralization, perhaps as much as 99 per cent, belongs to intrusions and especially to their later phases: it is therefore magmatic and the richness of the later small phases indicates differentiation and concentration in the magma-basins. There is a definite time-sequence, as follows: (1) contact

and border deposits, (2) internal segregations, (3) fissure and fault veins from deep-seated sources: furthermore, a definite primary zoning exists in the fissure-veins, and the horizon of ore-precipitation migrates regularly downwards in the successive stages of mineralization. All the facts here put forward are clearly consistent with the view that the mineralizing solutions are direct products of magmatic differentiation, when allowance is made for modifications introduced by the ordinary processes of chemical change and secondary enrichment that go on to a greater or less extent in all mineralized areas. This admirable study may be strongly recommended to the attention of all geologists interested not only in ore-deposits, but also in the theoretical side of petrogenesis.

R. H. R.

IX.—Report on the Inclusions of the Volcanic Rocks of the Ross Archipelago. By J. Allan Thomson. British Antarctic Expedition, Geology, vol. ii, pp. 131–51, with 3 plates and 3 text-figures. London, n.d.

NUMEROUS specimens of nodules and inclusions in the igneous rocks were examined by the author, who concludes that the olivine, pyroxene, and gabbroid nodules in the basalts and limburgites of Hut Point were formed by normal differentiation from the magma itself. In the trachytes and kenytes are found nodules of sanidine and plagioclase: it is not quite clear whether these are magmatic segregations or included xenoliths. Hornblendic inclusions in the trachytes, such as those at Observation Hill, are believed to be inclusions, but those at Cape Bird seem to be xenoliths of camptonite. The plagioclase-pyroxene inclusions in the trachyte of Mount Cis appear to be metamorphosed fragments of dolerite, possibly torn off from sills in the Beacon Sandstone. The quartz-bearing masses in the trachytes and kenytes are certainly altered fragments of impure sandstone: they contain a lot of glass and are very vesicular. There are, therefore, two distinct categories: (1) segregations, (2) xenoliths. It follows that parts of the Ross Sea are underlain by sandstones, probably faulted-down Beacon Sandstone and the presence of the lumps of dolerite confirm this idea, since in this formation dolerite sills are abundant and characteristic.

X.—Kongsbergfeltets Geologi. By C. Bugge. Norges. Geol. Undersök, No. 82, with English Summary. pp. 272, with 12 plates. Kristiania, 1917.

ALL the rocks of the famous Kongsberg mining district are of pre-Cambrian age, except certain diabase dykes, which are supposed to be post-Silurian. The older Knute formation consists mainly of volcanic rocks converted into amphibolites and gneisses, with some schistose sediments. Into these are intruded laccoliths of granite, quartz-mica-diorite, and gabbro-diorite, as well as hypabyssal representatives of these magmas; petrographical descriptions are given of these rocks and the properties of their constituent minerals are described.

The silver-ores of Kongsberg naturally come in for a good deal of attention; they are associated with fahlbands, that is, bands impregnated with sulphides, which originate from the Vinor diabase dykes. The silver-bearing veins contain chiefly native silver, with argentite, pyrargyrite, blende, galena, chalcopyrite, and pyrrhotite. These veins cut across the schists and are locally enriched in the fahlbands, most of the silver being concentrated at the intersections. The veins are of two generations, the sulphidic brecciated quartz veins being the older, while the well-known calcite-silver veins all belong to the second generation, and are apparently associated with the post-Silurian Kongsberg diabase dykes. The genesis of the ores is discussed in considerable detail.

XI.—Nogen Bemerkninger i Anledning av Seterne i Österdalen. By Dr. Hans Reusch. Norges Geol. Undersök, Aarbok for 1917, pp. 37, with English Summary. Kristiania, 1917.

THE distribution of erratics in the Österdal, the valley of the Glommen, in the eastern part of Southern Norway, indicates that during some part of the Glacial period the ice-shed lay to the south of the present watershed; hence it was argued that there should have been in the Österdal great ice-dammed lakes, like those that existed in Sweden and in Glen Roy. Dr. Reusch was, however, unable to find any signs of the existence of this ice barrier in the Storsjö region, where according to theory it ought to have been. He examined the "seterne" or inland raised beaches of this region, and has come to the conclusion that they were formed by summer-ponds lying on the surface of valley-glaciers during the melting stages; they are closely related to various eskers and side-moraines of the district, and a detailed study of these relations has confirmed his view. One of the figures, which are not numbered, gives a remarkably fine view of an esker near Röros. This paper may be recommended to the attention of students of glacier-lakes in this country.

XII.—Notes sur l'Érosion en Portugal. II. Les Lapiés des Calcaires au Nord du Tage. By E. Fleury. Comunic. da Commiss. do Serv. Geol. de Portugal, tom. xii, pp. 127–274, with 10 plates. Lisbon, 1917.

IN this immensely long paper, in French, the author discusses the character and origin of the peculiar denudational forms of limestone regions comprised under the various designations of lapiés, chaos, roches ruiniformes, rock-pillars, Karrenfelder, Dolinen, grikes, swallowholes, crevasses, and endless other names, comparing those seen in Portugal with the corresponding types of the Karst, the Jura, the Pyrenees, and many other regions. Since the paper runs to no less than 147 pages the reviewer freely confesses that he has not read it, but a cursory examination shows that it is an important contribution to an interesting subject. The precise meaning of the terminology employed by different authors is discussed in detail, and a kind of glossary with definitions is drawn up, which should be

very useful. Many of the plates recall in a remarkable degree the structures seen in the Mountain Limestone of the North of England.

XIII.—The Charters Towers Goldfield. By J. H. Reid. Geological Survey of Queensland, Publication No. 256. pp. 236, with 37 plates, 10 figures, and 25 plans. Brisbane, 1917.

AT one time Charters Towers had the greatest output of any Australian goldfield, the production in 1899 being 319,572 oz. of fine gold, but in 1916 this had decreased to 42,000 oz., and the writer of this memoir takes a gloomy view of the future. The geological relations of the gold ores are simple and of some interest from the theoretical point of view. The oldest rocks of the region are pre-Devonian schists, quartzites, and metamorphic limestones, penetrated by a batholith of granodiorite, and this again by dykes of aplite, quartz-porphyry, diorite, and porphyrite, the eroded surface of the whole being covered in places by patches of sandstone, possibly Tertiary. Two series of faults later than the dykes determine the position of the lodes, which strike N.–S. and E.–W. respectively. They may be described as simple and composite fissure lodes, up to 5 or 6 feet wide, with occasional "bulges" up to 50 feet in width. The vein-stuff is quartz, rarely calcite, carrying pyrites, galena, and blende, with occasional tellurides. Most of the gold was obtained from highly mineralized pay-shoots of irregular form, diminishing in value in depth. The vein-fillings are clearly of magmatic origin, belonging to Lindgren's type of siliceous gold ores of the middle depths, deposited by ascending solutions derived from the granodiorite magma. No gold values of any importance are found outside of the igneous rocks, and the association of the lodes with the porphyritic dykes is very definite.

XIV.—The Geology of the Country around Gatooma. By A. E. V. Zealley and B. Lightfoot. Southern Rhodesia Geological Survey, Bulletin No. 5. pp. 68 and 7 plates. Salisbury, 1918.

THIS memoir, written by the late Mr. A. E. V. Zealley and Major Lightfoot, records the results of a geological examination of about 600 square miles of territory some 200 miles north of Buluwayo, in the years 1912–14; about half of it is devoted to the geology, and the other half to the economic development of the region, with descriptions of the mines. The rocks in the area are almost entirely igneous, the dominant feature being a portion of a large granite batholith in the south-east corner, with other granite masses of smaller size on the west. Other rocks include porphyry, felsite, and greenstone, the two last names being wisely used in a very broad sense. One of the most interesting results of the field-work is the discovery that nearly all the "banded ironstones" exposed in the district are ferruginized and silicified felsite and quartz-porphyry. This obviously has an important bearing on the origin of the quartz-magnetite schists of other regions, both in South Africa and elsewhere, and especially the much-vexed

question of the origin of the ironstones of the Lake Superior region. The chief mineral product of the district is gold, which occurs both in quartz lodes and in replacement deposits of auriferous sulphides in fissured dissemination-zones. Antimonite lodes are known to exist, and scheelite has also lately been produced from quartz veins in felsite on the Scheelite King claim, and as a by-product from several gold-mines.

R. H. R.

XV. — Microscopic Secondary Sulphide Enrichment in the "Kuromono" Ore from the Kosaka Mine in the Province of Rikuchû, Japan. By Takeo Katô. Journ. Geol. Soc. Tôkyô, vol. xxv, pp. 7, with plate, 1918.

THIS is a study of the details of secondary enrichment seen on microscopic examination of a mixed pyrite-chalcopyrite-galena-blende ore. The secondary copper minerals observed are bornite, chalcocite, and covellite: these occur enclosed in chalcopyrite and are formed by metasomatic alteration of pyrite and chalcopyrite by descending solutions from the zone of oxidation above. The careful drawings reproduced in the plate are of considerable interest as showing clearly the order of formation of the different minerals and especially the development of bornite from chalcocite, a reversal of the usual order. Pyrite enclosed in blende has also been altered successively to bornite and covellite.

XVI. — The Ring-ore from the Akenobe Mine, Province of Tajima, Japan. By Takeo Katô. Journ. Geol. Soc. Tôkyô, vol. xxiv, pp. 35–41, with plate and 2 text-figures, 1918.

THE author describes concentric growths of ore and gangue minerals round fragments of silicified country rock in veins. The successive layers consist of (*a*) quartz with cassiterite, (*b*) chalcedony, (*c*) quartz. The interspaces contain fluorspar, scheelite, and siderite, and the whole is cut by numerous veinlets of chalcopyrite, forming a tin-copper ore. It is supposed that the second layer was deposited as gelatinous silica and afterwards recrystallized as fibrous chalcedony; this suggests that the veins were formed hydrothermally at a temperature below the critical temperature of water.

XVII.—Pre-History in Essex, as recorded in the Journal of the Essex Field Club. By S. Hazzledine Warren, F.G.S. pp. 44. Stratford and London, 1918.

MR. HAZZLEDINE WARREN has performed a useful service by bringing together in this publication a bibliography, with brief abstracts in most cases, of the papers dealing with prehistoric archæology in the widest sense, to be found in the Journal of the Essex Field Club. It covers a very wide range of subjects from the problem of pre-palæolithic man and the relation of palæolithic and glacial deposits to salt-making, wild-fowl decoys, and folklore, and cannot fail to be of great value to workers in this field of research.

XVIII.—Another Fossil Tze-Tze Fly.

FROM that extraordinarily rich deposit of Insecta at Florrisant, comes another Tze-Tze fly, found in 1916, by Mr. George Wilson. Mr. Cockerell, who describes it as *Glossina veterna* in the Manchester Museum Publication No. 80, remarks that it is a "truly marvellous specimen, showing not only the proboscis, wings, and body, but even the characteristic hairs". The wings, which are quite clear, measure 10·9 mm. As there are now four species of Tze-Tze fly known from Florrisant, Mr. Cockerell reminds us of Professor Osborn's suggestion that a fly carrying disease-producing organisms may have been a possible cause of the disappearance of the Tertiary herds which formerly occupied America.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *April* 9, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The following communication was read—

"The Section at Worms Heath (Surrey), with Remarks on Tertiary Pebble Beds and Clay-with-Flints." By William Whitaker, B.A., F.R.S., F.G.S. (With "Petrological Notes on the Beds at Worms Heath", by George MacDonald Davies, M.Sc., F.G.S.)

The chief pit now shows a fine set of more or less vertical pipes in the Chalk, filled with pebbles and sands of the Blackheath Beds, separated from the Chalk by Clay-with-Flints.

The pebble beds here, like those elsewhere, consist of well-rolled black flint pebbles, amongst which pebbles of a brownish quartzite are occasionally found. It is concluded that the water in which these flint pebbles were formed touched no other firm rock than Chalk; but, as there are no subangular flints, the deposition of the beds cannot have taken place close along a Chalk coast.

The great mass of these pebbles is confined to the western part of Kent and the adjoining part of Surrey, and they go but little way underground beneath the London Clay northwards. A few patches of pebbles at the same horizon have been mapped in the Hampshire Basin, but heretofore have not been classed as Blackheath Beds.

From a consideration of older Tertiary pebble beds, it seems that these are not big enough to have afforded the material for the Blackheath Beds. On the other hand, the Blackheath Beds may have yielded the pebbles of the Bagshot Series in Essex, though not in Hampshire.

An examination of the various Tertiary pebble beds (up to the Barton Series) points to overlaps of considerable extent; so much so that the probable thinning of beds below the Barton Sand, in the London Basin, and its former southward extension is comparable with the underground thinning of the Wealden and Lower Cretaceous in that area, though smaller and in a contrary direction.

As to the Clay-with-Flints, it is inferred that it is not a deposit of definite age, but a residual product, representing a condition of things that may have held through long geologic ages, from the start of the Blackheath Beds to the present time.

Mr. G. M. Davies gives a petrological description of the Chalk, of the Clay-with-Flints (both grey and red), of the Eocene sands, sandstones, and pebble beds. He also describes the presumed allophane originating from the base of the Eocene deposits, and discusses the probable sequence of events which resulted in the formation and infilling of the pipes and the deposition of the strata overlying the Chalk.

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2. *May* 7, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The President said: Major R. W. Brock, formerly Director of the Geological Survey of Canada, was called upon last year to undertake, on behalf of the War Office, an arduous journey in Palestine, during which he had to devote particular attention to the Dead Sea region. At the request of the officers of the Society, Major Brock has kindly undertaken to tell us something of his observations in the country. It is needless to say that the region is of surpassing interest to geologists, and I am sure that the Fellows will appreciate the opportunity of hearing how its remarkable features have impressed so acute and experienced a field-geologist.

Major Reginald W. Brock, M.A., F.G.S., then proceeded to deliver his lecture on the Geology of Palestine, his observations being summarized as follows:—

The following formations are recognized:—

QUATERNARY.	Alluvium.	Dunes; Valley and Plains Clay and Silt; Desert Crust.	Heavy volcanic flows, basalts, ashes, tuffs, etc.
	Diluvium.	Terrestrial. Lisan Formation (Jordan Lake Beds).	
		Marine. Upper Calcareous Sandstone and Limestone.	
		Lower Calcareous Sandstone.	
TERTIARY.	Pliocene.	Lacustrine.	
	Eocene	Nummulitic Limestone.	
MESOZOIC.	Cretaceous.	Upper — Senonian — Danian, Campanian, Santonian	volcanics, basalts.
		Upper — Turonian	
		Upper — Cenomanian.	
		Lower — Nubian Sandstone. Jebel-Usdum Formation (?).	
	Jurassic.	On Lebanon and Hermon only.	
PALÆOZOIC.	Carboniferous.	Possibly south-east of the Dead Sea.	
	Cambrian.	Dolomite and Sandstone.	
PRE-CAMBRIAN.	Volcanics and arkose.		
	Red granites and porphyries.		
	Grey granites, gneiss, and crystalline schists.		

The structure was shown to be that of a tableland bisected by a great rift-valley (Graben), and flanked by a coastal plain. A section was exhibited illustrating East Jordanland acting as a horst; the boundary faults of the Jordan Trench; the unequal sinking of the contained blocks; the western section of the tableland sunken with relation to the eastern, and thrown into an asymmetric anticline, the limbs of which rise in steps through monoclinal flexures or faults.

Lantern-slides were used to illustrate the character of the country and outstanding features in its geology, more particularly the following: the dependence of the topography upon geological structure, slopes depending on the attitude of the rocks and elevation upon the raising or depressing of fault-blocks or on lava-flows; basins and sunken areas in the tableland; the scarps bounding the Jordan Trench, especially the western fault and fault-blocks in the Trench or against its walls that hava not sunk equally with others; the upturned block of Jebel-Usdum which, with the Dead Sea bottom and the block north of Jericho, indicates a median fault between the boundary-faults; the interbanding of the Jebel-Usdum salt with sandstone and shales that resemble Nubian Sandstone; the unconformity of the Jebel-Usdum formation with the Jordan lake-beds (Lisan formation) which, with the chemical composition of the salt (lack of bromine, etc.), shows that it is not a Jordan lake-deposit; high lake-terraces in the centre of the Trench, with corresponding ones north of Tiberias and south in the Araba Valley, showing that the Jordan lake stood 1,400 feet above the present Dead Sea, and that there has been no marked warping since their formation; old gravel-filled cañons of the Arnon and Terka Main which prove that the level of the Dead Sea before Jordan-lake days stood at about its present level, and that climatic conditions must have been about the same, also that it did not long precede the Jordan lake; the Lisan formation of the Jordan lake-beds, thin layers of mechanical and chemical sediments veneered along the Jordan river with fluviatile clays; bad-land topography near the wadis and in the Lisan formation; narrow box cañons of the wadis in the Jordan Trench and the more open valleys above producing a sort of "hanging valley".

In the main, Blanckenhorn's recent work was confirmed, in particular the fault forming the western border of the Trench and disturbances and sinking in the tableland; but new points were mentioned, such as the evidence of a median fault within the Trench; the sea-cliffs of Lisan and Jebel-Usdum; the wave-cut shelf and the salt of Jebel-Usdum; the tilting of the Jebel-Usdum block and its independence from and unconformity with the old lacustrine beds; lack of disturbance and of warping since their deposition; the age and former level of the Old Dead Sea and the recent rise in the present sea, the latter indicating an increase in moisture and not drier conditions as generally supposed.

A vote of thanks was unanimously accorded to Major Brock for his lecture.